

# MONTHLY WEATHER REVIEW.

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## INTRODUCTION.

The present summary for 1902 is based essentially upon data received from about 166 regular Weather Bureau stations, 33 regular Canadian stations, and voluntary stations from such States as have forwarded their annual summaries in time. The statistical tables and charts have been prepared under the su-

pervision of Mr. W. B. Stockman, Forecast Official, in charge of the Division of Meteorological Records; the tables of movements of high and low areas by Mr. George E. Hunt, Chief Clerk, Forecast Division; and the summary of flood movements by Dr. H. C. Frankenfield, Forecast Official.

## FORECAST DIVISION.

Prof E. R. GARRIOTT, in charge.

### HIGHS AND LOWS OF 1902.

The high and low data for the year 1902 have been compiled under the general plan in use since 1895, and they differed but slightly in their general features from those of the preceding seven years.

The tables herewith give the summary for each month of the year 1902, and likewise a summary for the eight years from 1895 to 1902, inclusive.

*Summary of highs and lows for 1902.*

Month.	Highs.						Lows.					
	Mean first observed.		Mean last observed.		Path, average.		Mean first observed.		Mean last observed.		Path, average.	
	Lat. N.		Lat. N.		Length.		Lat. N.		Lat. N.		Length.	
	Long. W.	Long. W.	Long. W.	Long. W.	Duration, days.	Hourly velocity.	Long. W.	Long. W.	Long. W.	Long. W.	Duration, days.	Hourly velocity.
Jan . . .	46	116	40	72	2,978	4.0 35.4	45	104	44	69	2,109	2.8 33.7
Feb . . .	45	107	36	83	2,269	3.6 27.2	43	102	44	66	2,714	4.0 31.5
Mar . . .	45	113	41	65	3,496	4.6 31.8	38	110	45	74	2,568	3.5 29.7
Apr . . .	45	110	43	76	2,331	3.8 29.0	47	113	46	74	2,398	3.6 27.8
May . . .	50	104	40	68	2,522	4.3 24.7	42	103	44	72	2,032	3.0 28.2
June . . .	51	118	35	70	3,038	4.2 29.9	37	106	45	66	2,622	4.0 27.7
July . . .	47	111	38	77	2,265	3.4 29.0	41	112	45	70	2,224	3.3 31.1
Aug . . .	51	116	40	82	2,275	4.2 23.8	47	112	44	86	1,891	2.5 28.5
Sept . . .	50	117	45	72	2,606	3.7 32.8	46	112	45	76	2,452	4.0 26.6
Oct . . .	48	112	40	71	2,834	3.8 25.8	37	103	45	70	2,147	3.1 28.7
Nov . . .	48	114	41	82	2,245	3.1 32.6	42	109	45	73	2,264	3.4 28.2
Dec . . .	48	111	40	70	2,548	3.6 29.9	43	114	44	72	2,633	3.4 32.8
Means . .	48	112	40	74	2,616	3.8 29.3	42	108	45	72	2,338	3.3 29.5

*Summary, 1895 to 1902, inclusive.*

Year.	Highs.						Lows.					
	Mean first observed.		Mean last observed.		Path, average.		Mean first observed.		Mean last observed.		Path, average.	
	Lat. N.		Lat. N.		Length.		Lat. N.		Lat. N.		Length.	
	Long. W.	Long. W.	Long. W.	Long. W.	Duration, days.	Hourly velocity.	Long. W.	Long. W.	Long. W.	Long. W.	Duration, days.	Hourly velocity.
1895 . . .	47	110	39	80	2,445	3.8 24.4	45	107	45	73	2,109	2.8 33.7
1896 . . .	48	111	42	75	2,446	3.8 24.4	46	111	46	74	2,568	3.5 29.7
1897 . . .	48	113	38	78	2,446	3.8 24.4	46	110	46	71	2,398	3.6 27.8
1898 . . .	46	114	40	72	2,548	3.6 29.9	43	114	44	72	2,633	3.4 32.8
1899 . . .	47	114	41	72	2,444	3.8 24.4	46	111	46	68	2,264	3.4 28.2
1900 . . .	46	108	42	75	2,844	3.8 25.8	37	103	45	70	2,147	3.1 28.7
1901 . . .	48	112	41	75	2,245	3.1 32.6	42	109	45	73	2,264	3.4 28.2
1902 . . .	48	112	40	70	2,548	3.6 29.9	43	114	44	72	2,633	3.4 32.8
Means . .	47	112	40	75	2,616	3.8 29.3	42	108	45	72	2,338	3.3 29.5

George E. Hunt, Chief Clerk Forecast Division.

### RIVER AND FLOOD SERVICE.

The work of the River and Flood Service during the year has been noteworthy both by reason of the high standard of excellence attained by the officials in charge of the various centers in their warnings of impending floods, and by the broad extension of its field of operations. The demands for further enlargement have far exceeded our present ability in this respect.

The great floods of the year were those of early March in the rivers of the Middle and South Atlantic and east Gulf States, the Cumberland, Tennessee and upper Ohio; those of July in the Des Moines, upper Mississippi, and the extremely disastrous ones in the rivers of Texas, where the losses aggregated about \$15,000,000; and those of late November and early December in the Red River. Reference to the MONTHLY WEATHER REVIEWS for the respective dates will show with what accuracy and timeliness the warnings for these floods were issued.

New river centers and stations were established during the year as follows: Boston, Mass., with territory comprising the rivers of New England, having 14 river and 7 rainfall stations; Knoxville, Tenn., with territory comprising the Holston and French Broad rivers, having 5 river and 4 rainfall stations; Sioux City, Iowa, with territory comprising the Missouri River and tributaries from Sioux City to the headwaters, having 7 river stations. The Harrisburg district was also thoroughly reorganized and now has 8 regular and 1 special reporting river stations. A few new stations were established in other districts, and several less important ones were discontinued.

A considerable sum has been expended for improvements at the various stations, chiefly for new river gages, and the entire equipment, with but few exceptions, is now in excellent condition.

Before closing, mention should be made of the splendid service performed by the observers at the substations. These men and women, receiving only a meager compensation, by the careful and conscientious performance of the duties assigned to them, frequently under circumstances involving personal hardship and danger, have in no small measure contributed to the success of the work of the River and Flood Service.

The highest and lowest river stages for the year, together with the mean stage and annual range, at one hundred and thirty-seven selected stations are given in Table VII.—H. C. Frankenfield, Forecast Official.

## SPECIAL CONTRIBUTIONS.

## THE RED RIVER FLOOD OF NOVEMBER AND DECEMBER, 1902.

By J. W. CRONK, Observer, Weather Bureau, Shreveport, La.

The causes of this flood were (1) the heavy rainfall over eastern Texas during the early weeks of November; (2) later rainfalls over the watershed of the upper Red River; and (3) the quick succession of two or three heavy and quite general rains, both before and during the flood, over Oklahoma, Indian Territory, and western Arkansas. The combined result of these rains, falling in succession as they did the Sulphur, upper Red, and Little rivers, was a flood in the Red River at a time least expected by the oldest planters. By November 23 conditions had become so threatening that the Central Office at Washington advised that all necessary precautions should be taken for the removal of stock and property liable to damage by flood. On the 25th a general alarm was sounded by printing prominently on the local weather map the following warning: "*Red River is rising at all points; ample precautions should be taken for protection of property.*" From this date until the subsidence of the waters all points were kept constantly advised by daily forecasts, through the medium of the telegraph, telephone, the weather map, and the press.

At Arthur City, Tex., which was west of the flood line, the highest stage reached by the river was 25.6 feet on November 26, 1.4 feet below the danger line. At Fulton, Ark., within the flooded district, the river was above the danger line of 28 feet from November 25 to December 8, inclusive, reaching its crest stage of 32.2 feet on December 1. At Shreveport, La., and vicinity, where the maximum intensity of the flood was encountered, the river passed the danger line of 29 feet on December 6 and continued to rise slowly but steadily to a maximum stage of 34.1 feet on December 15 and 16. The water remained above the danger line until December 30, or in all a period of twenty-four days.

The flooded district was approximately 200 square miles in extent and comprised portions of southwestern Arkansas and northwestern Louisiana. That portion over which the greatest damage was wrought was a strip in Caddo Parish, extending in a north and south line for about 25 miles, and in some places over 6 miles in width. It began at an 800-foot crevasse in the levee at Elmer Bayou about 6 or 8 miles below the Arkansas-Louisiana line and extended southward to Shreveport, where the overflow waters again found their way into Red River by the way of Cross Bayou. Farms were badly cut up by the force of the immense volume of water, railroad bridges washed away, growing cotton destroyed, houses flooded, and some live stock drowned. Several towns were deprived of communication, save by boat or telephone, for several weeks. Fortunately but one life was lost, that of a colored man, who was either drowned or died from exhaustion near Gilliam, La. Across the river on the east side, in Bossier Parish, planters suffered considerable loss from overflow water that came in through the back country. The loss of property due to the flood aggregated more than \$500,000, but the value of that saved by the Weather Bureau warnings was easily as much and most likely more, although exact figures can not be given. The work of the Weather Bureau in connection with this flood has been characterized as "of incalculable benefit, as well as preventive of great loss of human life." Hundreds of press notices and letters commendatory in the highest degree have been received. The two following will indicate their general tenor.

Extract from a letter from Mr. H. Hawkins, Secretary of the Shreveport Board of Trade:

The flood warnings sent out by the Weather Bureau before and during the overflow were so accurate and timely that all had ample time to pro-

tect themselves. In consequence of said warnings, there was no loss of live stock and practically no loss of movable property. We have no data from which to compute actual value of property threatened from the overflow, but it runs into the hundreds of thousands. Certainly the Weather Bureau did wonderful work.

From Belcher, La., one of the towns cut off by the flood, Mr. John A. Hall, Postmaster, writes as follows:

The benefits derived from warnings during the recent flood in Red River were incalculable. Ample time was given for the removal of live stock, grain, and produce from lowlands to places of safety. All gave heed to the warnings, which were greatly appreciated. The forecasts were correct in almost every particular, and the work of the Weather Bureau has been highly commended by all.

## CANNON AND HAIL.

By Prof. J. R. PLUMANDON, Professor at the University of Clermont-Ferrand and Meteorologist at the Observatory of the Puy de Dome, France, dated January 18, 1903.

From the most ancient times men have had the audacity to fight against storms by threatening Heaven with their weapons. In the time of Herodotus they hurled arrows in the air, to-day they discharge cannon. It is true that they no longer hope to intimidate an angry divinity, but they are convinced that they will be able to conquer nature and destroy storms.

Firing cannon to protect the crops from hail is a usage that goes back to the sixteenth century at least, and which has up to the present time passed through many alternate phases of success and failure, or even periods of complete oblivion. For the last few years we have been witnessing an extraordinary revival of this practise which has acquired a remarkable development in Austria, Italy, and even in some departments of France.

In 1880 and 1884, M. Bombicci, Professor of Mineralogy in the University of Bologna, Italy, maintained that it was possible to prevent the formation of hailstones during thunderstorms by the discharge of cannon which would carry the dust that causes condensation into the midst of the clouds. Some years later, about 1891, basing his views upon the experiments made in Texas, U. S., by General Dyrenforth in order to produce rain, Bombicci even proposed the same method to dissipate hailstorms and force them to discharge only a beneficial rain, or, at most, harmless sleet.

On June 4, 1896, Bombicci's plan was put into execution by M. Stiger, Burgomaster of Windisch-Feistritz, Styria, who made use at first of simple slightly elongated mortars to bombard those clouds that looked stormy. Only a little rain fell, the clouds disappeared and the experimenters attributed this good result to the cannonading. The same results were obtained under analogous conditions in the course of that year, 1896, and also in 1897, so that the cannonading stations began to increase. They numbered 56 in 1898, and at that time mortars, lengthened by the addition of a bell-mouthed chimney, shaped like the trunk of a cone, were used. This is the type of cannon in use at present, and known as "agricole" (agricultural) or "grelifuge" (hail preventing) and which has been perfected so that it renders the firing convenient and rapid.

According to a translation by M. Ottavi, Deputy in the Italian Parliament, the following paragraph occurs in M. Prohaska's official report on the results obtained in Styria during the year 1898:

It may be stated that the firing has produced good results only at Windisch-Feistritz where the success of the two preceding years has been maintained. In the other localities it has not been at all satisfactory. The negative results are all the more surprising since the firing was begun in time and carried on perseveringly. \* \* \* However, although the experiments of 1898 do not justify us in coming to a definite conclusion as to the practise of firing into the clouds it is necessary to continue what has been begun.

## CONGRESS OF CASALE IN 1899.

Notwithstanding these results, in general unfavorable to the idea of the protection of the crops by means of cannon, numerous associations for cannonading were formed in Italy, particularly in Venice, Lombardy, Piedmont, and Emilia. At the end of the year 1899 there were already more than 2000 cannon there, and the vine growers of upper Italy after the thunderstorm season was over, called together a special congress at Casale in order to make the results obtained by the firing known and appreciated. M. Ottavi, who a few months before had advised his compatriots not to be too hasty in following the example of Styria, accepted the presidency of the committee on organization of this congress. More than 600 delegates met at Casale in November, 1899, under the presidency of M. Bombicci, and voted nearly unanimously for the following order of the day.

The congress after having inquired into the results obtained by the experiments carried on in Styria, Dalmatia, Piedmont, Lombardy, Venice, Emilia, and Tuscany is convinced:

1.—That the cannonading has made the prospect for the solution of the great problem of preventing hail very encouraging.

2.—That the results attained this year could not be more full of promise.

The congress expresses the hope that the regions in which the first experiments have taken place this year may succeed in perfecting the means of protection, taking as a basis the experience already acquired.

## CONGRESS OF PADUA IN 1900.

The conclusions of the previous congress were by far too optimistic, they raised the enthusiasm of the vine growers to the highest pitch and the cannonading began to spread into Hungary, Spain, and southeastern France. But it was especially in Italy that the number of cannon increased to a surprising extent. In less than one year, in the province of Venice, they increased from 446 to 1630; in Brescia from 260 to 1455; and in Treviso from 87 to 1334, etc. In short, at the end of 1900, 10,000 cannon were distributed in groups among the vineyards of upper Italy, and 9,500,000 discharges had taken place. This tremendous agricultural artillery, unfortunately, did not work without accidents, and in Venice alone, where there were 3000 cannon, 7 deaths and 78 wounded were reported.

The increase in number of associations for cannonading as a protection against hail led to the calling together of a second international congress which took place at Padua at the end of November, 1900, under the presidency of M. Alpe, professor at the high school of agriculture, at Milan.

Among the papers communicated to the congress, one remarks especially the report of M. Pochetino, director of the station for the study of hailstorms established at Conegliano, in Venice, by the Italian Government. It merits particular attention, not only on account of the guarantee afforded by a control, at once scientific and official, but also because it gives a general idea of the value of the facts invoked for or against the efficacy of the cannon. M. Pochetino, after having cited a great many facts in regard to the action of the firing upon the formation of hail, divided them into five categories, viz:

*First category.*—Where notwithstanding regular firing, hail fell within the boundary of the protected region and caused a loss of more than ten per cent of the crop. To this category belong the facts observed at Volpago, June 22, 1902, where notwithstanding the fact that the cannon were fired 2250 times, a narrow ridge of hail crossed the protected region. The failure was still greater at Monastier on the 10th and 11th of August, since the 100 stations began to fire a half-hour before the storm and in spite of 6000 shots and charges of from 80 to 150 grams, a storm of extraordinary violence devastated that commune and the losses reached 90 per cent.

*Second category.*—Where the hail fell within the boundaries of the protected regions, but the firing was irregular. This

class includes the defense of the communes of Mogliano, May 25; Collabrigo, July 30; Castello di Godago, August 11; Castelfranco, August 11; Crespano, August 11, and Mogliano, August 11.

*Third category.*—Where the firing took place and very little hail fell, doing no damage, outside as well as inside of the protected region. This occurred at Panderoba and Tanaro, May 8, 15, 25; Caerano and Volpago, June 22; Vazziola, June 18; Fontanelle, Spreziano, Salgareda, and Monastier, July 8; Caraso, July 11, 21, and 23.

*Fourth category.*—Where the firing took place and no hail fell within the protected region, but in localities situated outside of its limits the hail was very severe: Monegliano, June 18; Conegliano, June 26; Castelfranco, July 18; Monastier, August 7; Villorba, August 11.

*Fifth category.*—Where the firing was irregular and the damage was less severe around the firing stations. This comprises the partial successes of Gajarine, July 8, and of Losson du Molo, August 11.

The following are the personal opinions of the reporters for the various regions, as quoted from the report of M. Houdailles, delegate to the Congress of Padua for the Minister of Agriculture of France:

*Austria.*—M. Suschnig, Director of the Iron Works of Ste. Catherine on the Lamming, Styria, concludes by saying "that it is necessary to seek to explain the effects of the cannonading, which are still unknown to us."

*Hungary.*—M. Raum, First Assistant at the Observatory of Budapest, does not think that he can give a definite opinion as to the efficacy of the cannonading, "for," says he, "we can not be too prudent as regards this question."

*France.*—M. Guinand declares that "if complete protection under all possible circumstances can not be assured, at least it can not be denied that results of great importance have been obtained and that they constitute important indications for the future."

*Piedmont.*—M. Rizzo, Professor at the University of Pérouse, concludes his report by saying that "up to the present time the facts collected and verified are not yet sufficient to furnish a solution to the problem of the efficiency of the cannonading."

*Lombardy.*—M. Tamaro, Director of the Agricultural College at Crumello del Monte, maintained that "recent facts, confirmed by thousands of stations, can but serve to establish perfect confidence in the protection of the crops by cannon, and he hoped that when the congress was over no doubts would remain as to the efficiency of the firing."

M. Sandri, Director of the Agricultural College of Brescia, went even further, and, as a consequence of the proofs of the efficacy of the shooting, he called for a vote recommending a law that should render obligatory the protection by cannonading when this protection is demanded by a majority of those interested.

*Venice.*—M. Pochetino, director of the stations for the study of hailstorms at Conegliano, declared that "it is impossible to pronounce, from a scientific point of view, as to the efficacy of the firing, and that this question can only be really practically demonstrated by statistics of actual damages, studied with care and impartiality, with the aid of observations collected for several years."

M. Arina, Director of the Agricultural School at Susegana believes that the protection of the crops by the firing of cannon is destined to achieve substantial success in the future, but he recommends that no new syndicates for cannonading be formed and that those already existing be improved. He also proposes the establishment of experimental zones in order to insure more accurate data as to the efficacy of the shooting against hail.

*Other provinces in Italy.*—MM. Tago and Marengi, Professors of Agriculture, admitted that the system of cannonading was established on a solid basis, and that when the organization shall have been perfected, it will be successful, at least in cases of ordinary thunderstorms.

The Congress of Padua, after the reading of the various reports, as well as the testimony of the delegates as to the efficacy of the firing, adopted nearly unanimously, the resolution of M. Porro, Director of the Astronomical Observatory of Turin, as follows:

This congress, after having heard the reports and successive discussions upon the results obtained during the year 1900, in Italy and in other countries, considers the great efficiency of shooting as a protection against hail as having been proved beyond all question.

As had already happened the year before at Casale, the conclusions of the Congress of Padua were far from being in perfect harmony with those expressed by the reporters. This arose from the fact that after each partial report the conclusions of the reporter were discussed and put to vote, but were generally adopted only after certain modifications that changed them considerably. The result was that in general the opinion of the assembly was substituted in an irrational manner for that of the reporters. The weight of the conclusions of this congress was thereby greatly diminished.

#### CONGRESS OF LYONS IN 1901.

Thanks to the persevering and persuasive activity of M. Guinand, Vice-president of Agricultural Union of southeastern France, who had participated in the congresses of Casale and of Padua, the use of cannon against hail continued to spread in France, especially in the Beaujolais where, in 1901, 300 cannon were in operation, covering a continuous region 10,000 hectares in extent. This enthusiasm was not, however, to be compared with that manifested in Italy, since over the whole of France it led to the establishment of only 834 cannon, of which 666 were in the departments of the Rhone, Saône et Loire, and Loire. It must, moreover, be admitted that even in Italy, doubtless as a consequence of previous efforts, the great ardor of the preceding years seemed not only to have subsided, but in some regions to have given place to a veritable discouragement.

The experiments of the year 1901 were the basis of a third international congress, and 1950 delegates met in Lyons on the 15th, 16th, and 17th of November, under the presidency of M. Burelle, President of the Regional Society of Viticulture. In the reports and discussions at the Congress of Lyons are found, even more than at the Congress of Padua, side by side with the ardent affirmations of the partisans of the efficacy of cannon against hail, the doubts and the wise reserve of those who wish for proofs; at times one heard even rather excited negotiations, proceeding from Italy as well as from France.

The following are some of the conclusions of the various reporters called upon to judge of the efficacy of the shooting, in the order in which they were presented to the congress:

*France.*—To-day the agricultural cannon seem to be able to clear up our viticultural horizon, arrest the thunder, the lightning, and the wind, disperse the clouds, and cause the sun to shine in a cloudless sky. This is the unanimous statement found in all the reports from our stations; it is certainly a fine work.—M. Guinand, Vice-president of the Agricultural Union of the southwest.

*Austria.*—All this does not suffice to enable us to consider the theory of cannonading as solved, and I share the opinion of our scientists who say that the efficacy of hail shooting can only be demonstrated by practise.—M. Suschnig, Director of the Iron Works of Ste. Catherine on the Lamming.

I can not prove scientifically whether the effect produced on the storm is due to chance or not, but I can prove that not a single stroke of lightning has occurred in the region provided with firing stations or in its neighborhood.—M. Stiger, Burgomaster of Windisch-Feistritz.

*Italy: Piedmont.*—At our local congress at Novara M. Rizzo, who has been studying the question on the spot for the past two years, told us that he has not yet been able to conclude with certainty that the discharges have any effect against hail. As to myself, I will say to you that I, on my part, have been studying the question in a practical manner for three years, that I have not had any hail, but I must ask you for still a few years more of observations and experiments before I can express a definite opinion.—M. Ottavi, Deputy to the Italian Parliament.

*Italy: Lombardy.*—The local congress of Novara, after having heard the reports on the shooting against hail, considers these as confirming the good results of 1899-1900, in regions where the associations have cannonaded regularly with sufficient means, and where no thunderstorms of exceptional violence have occurred. From this conclusion we may draw the inference that the problem of protection against hail is not entirely solved. In order to abridge the time and expense of the experiments it would be useful for the governments to organize completely and rationally several associations for cannonading, reserving to itself the right of official supervision of the results obtained each year. In this way alone the interpretation of observed facts would not be modified by the prejudices of those by whom they are examined and discussed, and the vineyardists would be correctly informed as to the efficacy of the practise of shooting toward the clouds. This is the expression of my personal opinion.—M. Alpe, Professor of the High School of Agriculture of Milan, Ex-president of the Congress of Padua.

*Italy: Emilia.*—In conclusion, I find that up to the present time we have not yet the reliable facts upon which one would be justified in asserting that the practise of cannonading has passed beyond the first stage of experimentation. No definite opinion whatever can be formed, even if the methods should be perfected, for from ten to twelve years from this time.—M. Marescalchi, Director of the Cultivatore.

*Italy: Udina, Belluno, Treviso, Verona, and Venice.*—For my part, after having examined personally several of the principal cases and after having heard many accounts from different sources, I am perfectly convinced that whenever we have rational establishments equipped with suitable means of defense and with a staff of disciplined and intelligent officials we may combat ordinary hailstorms with every prospect of success.—M. Marconi, Professor of Agriculture at Venice.

*Switzerland.*—As a whole, the results obtained in Switzerland are still inconclusive. They are not, however, such as to discourage us, since there have not been any notable marked failures; on the contrary, in several cases the shooting seems to have produced some good effect. But an experience of one year does not prove anything. Many years of experiment at our various stations will be necessary before we can confidently state what the results of the cannonading really are.—M. Dufour, Director of the Viticulture Station at Lausanne.

*Spain: Barcelona.*—As regards the results in the region under protection, and although no severe hailstorms have occurred in which the decisive effect of the cannon could be demonstrated, nevertheless there have, at least, been several cases that make us hope for great success.

We see in the experiments thus far made results very favorable to the solution of a problem which is of interest to the agriculturists of the whole world, and our conviction is that the regions well supplied with cannon, properly distributed over their zone of action, will hereafter be able to protect their crops against hail, especially if, in addition to a good organization for the shooting, there prevail the enthusiasm and the faith which are necessary in order to achieve success among the agriculturists of the protected zone.—M. Garcia de los Salmones, Director of the Agricultural Service of Navarre.

*Russia.*—The land that has always suffered five or six times annually from hail has been entirely exempt from it this year, whereas in the surrounding regions the crops have been destroyed as usual. It is true that it is impossible to draw any conclusion as to the utility of the firing from the experience of a single year, but I am happy to be able to state that no case of failure has occurred to diminish the confidence first felt.—Gogol-Janovsky, Director of the Vineyard of the Imperial Domains at Tiflis.

After several other reports relative to the organization of zones of protection from the financial and legal point of view, M. Roberto, supervisor of education at Alessandria, Italy, and reporter general for Italy, concludes as to the efficacy of the cannon against hail in ordinary storms by admitting the impossibility of destroying very violent hailstorms.

M. Plumandon, reporter-general for all the countries represented at the congress, concludes that the proofs adduced in favor of the efficacy of cannon against hail are practically without any value; that this alleged efficacy seems to him very problematic and almost impossible; that finally in order to elucidate the question it is at least necessary to make the experiments in accordance with scientific methods, to accept no fact that had not been submitted to a severe investigation, and above all not to adopt any conclusion until it had under-

gone rigorous criticism and examination. After some remarks upon the organization of such supervision the reporter terminated by wishing success to the experimenters.

The reading of reports having been concluded, M. Burelle, President of the Congress, then addressed the reporters and said that the question of the employment of cannon against hail presents itself under conditions such that neither science nor agriculture can afford to ignore it. Animated by this thought he submitted to the vote of the congress the following resolution:

The Third International Congress on Hail Shooting, assembled at Lyons, November 15, 16, and 17, 1901, after having listened to the reports and the results obtained during the year 1901, in France, Austria, Hungary, Italy, Spain, Switzerland, and Russia, comes to the conclusion that the question of protection against hail is worthy of the attention and study of scientists and the confidence and hopes of agriculturists.

The congress adopted this resolution, together with several others, relative to the organization of the zones of shooting.

#### CONFERENCE AT GRATZ, 1902.

After the Congress of Lyons a calm succeeded to the general effervescence and the protection of crops by cannonading did not experience any notable increase. As regards France we may judge of this by the small increase in the number of cannon in Beaujolais, viz.: 340 cannon in 1901; 357 in 1902. However, in this connection an interesting event took place, viz., the meeting at Gratz (Styria) which was a conference of experts under the auspices of the Austrian Minister of Agriculture.<sup>1</sup>

It would occupy too much time and space to enter in detail into the reports, experiments, and discussions with which the sittings were occupied, we shall, therefore, only call attention to the following table, which summarizes well and briefly the results of the labors of the conference:

Number of experts in whose opinion cannonading is efficacious . . . .	8
Number of experts in whose opinion the efficacy is still doubtful, but probable . . . . .	9
Number of experts in whose opinion the efficacy is only doubtful . .	13
Number of experts in whose opinion the efficacy is not only doubtful, but improbable . . . . .	15
Number of experts in whose opinion cannonading is entirely inefficacious . . . . .	5
	50

*Conclusion.*—The preceding paragraphs present as briefly as possible, the successive phases of the recent efforts made in Europe to destroy hailstorms by the aid of cannon. A simple comparison of the reports and conclusions which have appeared annually from 1898 to 1902, is very instructive and calls forth the following important remark, viz., that the thoughtless and ill-informed enthusiasm which distorted the first discussions on the efficiency of cannonading against hail has gradually given place to the calmer and more serious judgment which led the Congress of Lyons and still more the Conference of Gratz to conclusions more rational and more in harmony with the nature of the phenomena to be investigated as well as of observed facts.

It would be easy to explain the origin and spread of the first enthusiasm; why many sincere people were conscientiously brought to judge too favorably of experiments which did not prove anything; but that would lead to too much detail. The general statement, above given, which constitute, so to speak, the abridged history of the bombardment with cannon against hail, will suffice to show how circumspectly we must proceed when we wish to judge of the efficacy of human intervention

<sup>1</sup> This is published in full in an appendix to the annual volume for 1902 of the Central Institute for Meteorology and Terrestrial Magnetism.

against the great forces called into play by nature for the production of thunderstorms. They also show that we should not discount too quickly the advantages that we may hope to derive from such enterprises. If it were necessary to conclude by a plain unvarnished admonition, the following is what I would say: *Before undertaking the protection of your crops by cannonading, wait until that method of protection has furnished good results in countries where it is now being tried.*

#### STUDIES AMONG THE SNOW CRYSTALS DURING THE WINTER OF 1901-2, WITH ADDITIONAL DATA COLLECTED DURING PREVIOUS WINTERS.

By MR. WILSON A. BENTLEY, dated Jericho, Vt., June 10, 1902.

At the request of the Editor, I gave in the MONTHLY WEATHER REVIEW, for May, 1901, a brief sketch of my twenty years of study among snow crystals, illustrating it by about twenty-five examples of photomicrographs of snow forms. He desired me to give at that time a more complete account of my studies and also wished for a much greater number of photomicrographs for illustration. I was unable to accede wholly to his request, but I offered to devote myself during one or more succeeding winters to the gathering of all the data and photomicrographs possible and furnish material for a more complete account; my earnest desire being that I might, in this manner, contribute my mite to the general fund of scientific knowledge. No time, pains, or expense have been spared to make this sketch of the past winter's work as complete as possible.

It is sincerely hoped that the reproduction of the photomicrographs of these marvelously beautiful objects of nature will give great pleasure to many students. Possibly both photomicrographs and text may be of some positive value in an educational way, calling the attention of both the specialist and the general public to these most interesting examples of the handiwork of nature, and to the mysterious laws by which they are evolved from the invisible and seemingly unintelligent particles of matter, called water vapor, floating in our atmosphere.

I am greatly indebted to the Chief of the Weather Bureau, and to Mr. John W. Smith, Weather Forecast Official for New England, for weather maps furnished or loaned to me, and to Mr. E. H. Nash for invaluable services rendered me in changing and numbering exposed plates, so that more time could be devoted to the search for, and the photographing of, the forms.

The endeavor has always been made to secure characteristic sets of photomicrographs from each storm; yet, singularly enough, this proved the most difficult task of all, because the old habit of seeking for the beautiful and interesting, rather than the characteristic types, was very difficult to overcome. For this reason, I fear the winter's photographic record portrays far more fully the general character of the beautiful and interesting than it does the broken or unsymmetrical types. And yet there are few, perhaps, who after viewing the feast of beauty filling these pages will regret our shortcomings in this regard, especially as the general characteristics of the forms, from time to time, are given with some fullness in the accompanying text.

The winter of 1901-2 proved to be extremely favorable for our work and the number of photomicrographs (over 200) was much greater than that secured during any previous winter; the forms also greatly exceeded in beauty and interest the contributions of any other single winter. The dates and characters of the several snowstorms are given in Table 1. Beautiful and perfect forms occurred on twenty-one different days as against ten for the winter of 1900-1901, which was the next most favorable on record.

TABLE 1.—*Meteorological data for snowstorms.*

Date.	Numbers of photomicrographs.	Temperature.	Pressure.	Wind.	Clouds.	Portion of the storm field.
		<sup>°</sup> F.	Inches.			
1901.						
Nov. 25	700-703	29	29.6	n.w.	Stratus and detached low nimbus*.	Central-western.
Nov. 26	704-721	26, 23	29.6	w.	Stratus and nimbus*.	Central-west.
Nov. 27	722-726	9	30.2	w.	Stratus and nimbus.	Western edge.
Nov. 28	727-729	7, 13, 8	30.1	w.	Thin stratus above, detached nimbus below.	Extreme western edge.
Nov. 30	730-737	18	30.0	wnw.	Thin stratus and nimbus.	Undetermined.
Dec. 4	738-745	17	29.8	w, n.w.	Stratus above, low nimbus send below*.	Western.
Dec. 5	746	7, 4	30.1	n.w.	Thin nimbus.	Western edge.
Dec. 15	747-774	25, 20	29.8	ne.	Stratus and nimbus*.	Western-central.
Dec. 25	775-779	27	29.8	w.	Dense stratus, detached low nimbus*.	West-central.
1902.						
Jan. 1	779 <sup>1</sup>	-10	30.3	n.	Thin stratus or clear.	Extreme western edge.
Jan. 5	780-797	24, 25	30.4	n, n.w.	Stratus and few low nimbus.	Western edge.
Jan. 10	798-808	15, 25	29.5	w.	Cirro-stratus above, stratus and nimbus below.	Southwestern.
Jan. 12	809-833	19, 15	29.4	w.	Clouds hidden by heavy snowfall.	Southwest-central.
Jan. 14	834-838	9, 7	29.6	n.w.	Stratus and nimbus*.	Southwest edge.
Jan. 19	839-842	21, 15	29.9	n, n.w.	Low nimbus*.	Western.
Jan. 21	843-848	15, 19	30.1	se.	High cirro-stratus, thin detached nimbus.	Southwest.
Feb. 7	849-856	12, 18	29.2	w.	Cirro-stratus, few nimbus.	Southwest edge.
Feb. 8	857-887	8	29.4	w, n.w.	Stratus and nimbus*.	Southwest.
Feb. 10	888-896	10, 20, 5	30.0	n.w.	Thin stratus, low nimbus.	Extreme western edge.
Feb. 13	897-900	9, 14	29.8	n, ne.	High cirro-stratus.	Western portion.
Feb. 17	901-905	8, 29	29.8	n, n.w.	High cirro-stratus followed by low clouds.	Northeast edge at first, central at the last.
Feb. 18	906-922	14, 25	29.1	n.w.	Unknown.	Central-west.
Feb. 19	923-933	7, 15	29.6	n.w.	Low nimbus*.	
Mar. 19	934-938	15, 21	29.6		Cirro-stratus, stratus, detached low nimbus in the afternoon.	West portion.

\*On all these dates Mr. Bentley records "probably high cirrus or cirro-stratus above." As this is an inference drawn by him from the general structure of storm clouds, and the appearance of the forms of the snow crystals, we do not include it in the column of observed clouds.—*Ed.*

A list of the dates and serial numbers of selected photomicrographs is given in Table 2; this list includes all that were taken during 1901-2, and some interesting forms photographed in previous years. The data secured during the winter of 1901-2 are very instructive, not only because of the great number of snowstorms and the variety of the weather conditions prevailing therein, but also because our study of the weather maps in connection with the data allowed of the attainment of much more complete and exact results than otherwise would have been possible. It may be noted that, in general, the data and photomicrographs secured tend to further confirm the observations and conclusions arrived at by virtue of the studies of previous years.

We have not yet attained to any positive knowledge, but have been able to frame plausible hypotheses as to the conditions or factors governing the occurrence of the nuclear forms; we are still kept in doubt as to why columnar nuclei are produced at one time and tabular nuclei at other times. In general our data tend to further confirm the conclusions of all observers, that a more or less intimate connection exists between form and size of nuclei, and the altitude and temperature of the air in which the crystals form. There can be no longer any doubt that there is a general law of distribution of the various types of crystals throughout the different portions of a great storm. On this point the data secured, both by direct observation and by a study of the weather maps, are much more complete and satisfactory than has ever before been published. This aspect of our study received special consideration, because it was thought to be most important.

Snowstorms often cover a region of vast extent; crystallization is going on within them over nearly the whole area, and therefore in regions that differ greatly among themselves as to temperature, humidity, air density, electrical conditions, etc. Moreover, the kind, number, dimensions, altitude, and density of the clouds within those various regions differ so greatly one from another that the snow crystals emanating from each region furnish us rare opportunities for observing and studying the effects of each of these various conditions upon the forms.

The accompanying weather map for 8 a. m., December 4, 1901 (fig. 1), shows quite clearly the great extent of our winter snowstorms, and the very various weather conditions prevailing within them. Perfect snow crystals were falling over northern Vermont when this map was drawn, and the location of the low, or storm center, as regards our locality at Jericho,

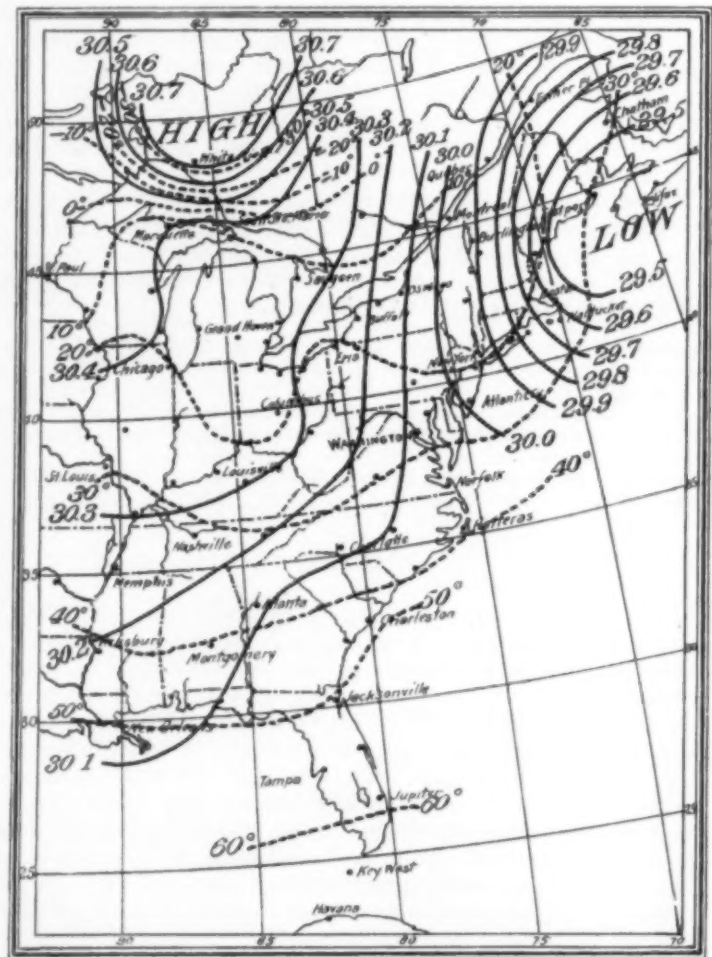


FIG. 1.—Weather map of December 4, 1901, 8 a. m.

Vt.<sup>1</sup> was approximately identical with that of the positions of most storm centers when perfect forms have occurred. Perfect crystals emanated from the southwestern portion of this storm, and, in general, the great majority of perfect forms are produced within the western, southwestern, or northwestern portions of such widespread storms.

<sup>1</sup>Jericho is about 15 miles east of Burlington, Vt.

TABLE 2.—Chronological list of dates of photomicrographs, with corresponding serial numbers.

No.	Date.	No.	Date.	No.	Date.	No.	Date.
10	Feb. 26, 1886	732	Nov. 30, 1901	801	Jan. 10, 1902	870	Feb. 8, 1902
19	do	733	do	802	do	871	do
47	Mar. 12, 1888	734	do	803	do	872	do
64	Dec. 14, 1889	735	do	804	do	873	do
76 a	Jan. 5, 1892	736	do	805	do	874	do
92	Feb. 12, 1892	737	do	806	do	875	do
108	Feb. 16, 1893	738	Dec. 4, 1901	807	do	876	do
198	Feb. 15, 1896	739	do	808	do	877	do
227	Jan. 23, 1897	740	do	809	Jan. 12, 1902	878	do
257	Jan. 5, 1898	741	do	810	do	879	do
270	Jan. 26, 1898	742	do	811	do	880	do
342	Nov. 27, 1898	743	do	812	do	881	do
359	Jan. 6, 1899	744	do	813	do	882	do
405	Feb. 13, 1899	745	do	814	do	883	do
433	Mar. 18, 1899	746	do	815	do	884	do
482	Feb. 18, 1900	747	do	816	do	885	do
488	do	748	do	817	do	886	do
493	Feb. 19, 1900	749	do	818	do	887*	do
503	Mar. 2, 1900	750	do	819	do	888	Feb. 10, 1902
504	Dec. 5, 1900	751	do	820	do	889	do
513	Dec. 27, 1900	752	do	821	do	890	do
529	Jan. 7, 1901	753	do	822	do	891	do
547	Jan. 28, 1901	754	do	823	do	892	do
561	do	755	do	824	do	893	do
562	Jan. 31, 1901	756*	do	825	do	894	do
564	Feb. 5, 1901	757	do	826	do	895	do
565	do	758	do	827	do	896	do
580	do	759	do	828	do	897	Feb. 13, 1902
581	Feb. 13, 1901	760	do	829	do	898	do
582	do	761	do	830	do	899	do
583	do	762*	do	831	do	900	do
584	do	763*	do	832	do	901	Feb. 17, 1902
585	do	764*	do	833	do	902	do
587	do	765	do	834	Jan. 13, 1902	903	do
591	Feb. 15, 1901	766	Dec. 5, 1901	835	do	904	do
593	do	767	Dec. 15, 1901	836	do	905*	do
594	do	768	do	837	do	906	Feb. 18, 1902
598	do	769	do	838	do	907	do
700	Nov. 25, 1901	770	do	839	Jan. 19, 1902	908	do
701	do	771	do	840	do	909	do
702	do	772	do	841	do	910	do
703*	do	773	do	842	do	911	do
704	Nov. 26, 1901	774*	do	843	Jan. 21, 1902	912*	do
705	do	775	Dec. 25, 1901	844	do	913*	do
706	do	776	do	845	do	914*	do
707	do	777	do	846	do	915*	do
708	do	778	do	847	do	916*	do
709	do	779	do	848	do	917*	do
710	do	779	Jan. 1, 1902	849	Feb. 7, 1902	918*	do
711	do	780	Jan. 5, 1902	850	do	919*	do
712	do	781	do	851	do	920	do
713	do	782*	do	852	do	921	do
714	do	783	do	853	do	922*	do
715	do	784	do	854	do	923	Feb. 19, 1902
716	do	785	do	855	do	924	do
717	do	786	do	856	do	925	do
718	do	787	do	857	Feb. 8, 1902	926	do
719*	do	788	do	858	do	927	do
720	do	789	do	859	do	928	do
721*	do	790	do	860	do	929	do
722	Nov. 27, 1901	791	do	861	do	930	do
723	do	792	do	862	do	931	do
724	do	793	do	863	do	932	do
725	do	794	do	864	do	933*	do
726*	do	795	do	865	do	934	Mar. 19, 1902
727	Nov. 28, 1901	796	do	866	do	935	do
728	do	797	do	867	do	936	do
729*	do	798	Jan. 10, 1902	868	do	937	do
730	Nov. 30, 1901	799	do	869	do	938	do
731	do	800	do				

\*Omitted. Photomicrographs unsatisfactory.

†The negative was injured, but has been repaired, as will be apparent to the reader.

‡This photomicrograph is, by mistake, numbered 100 on Plate I.

TABLE 3.

Storm portion.	Number of occurrences of perfect forms.	Columnar.	Solid tabular.	Stellar or solid nuclei.	Fern stellar.	Doublets.	Long needle-shaped.	Granular.
N	10	8	7	9	6	1	2	3
NE	5	3	4	5	2	3	1	2
E	3	3	1	3	6	1	2	3
SE	1	1	1	1	1	0	0	0
S	1	0	1	1	6	1	2	3
SW	16	10	14	15	14	6	2	8
W	20	9	19	20	17	2	5	8
NW	10	3	10	10	9	3	0	7
Total occurrence of each type...	66	37	57	64	61	17	14	34
Deduct from the above the forms emanating from the central portions of these storms that passed across our locality	14	7	9	12	11	9	3	6
Balance	52	30	48	52	50	8	11	28

Table 3 gives the number of occurrences of perfect forms and of other types within the respective quadrants about the storm centers during the four winters 1897-98 to 1901-2, inclusive, so far as shown by photomicrographs. The whole number of such storms depositing perfect forms at our locality was 64.

As will be noted, about five-sixths of the perfect forms occur within the west and north quadrants of great storms. Their appearance within other portions, especially within the south and southeast quadrants, is rare indeed.

The classification by form and structure of the various types referred to in this and the following tables will now be described briefly. Prof. G. Hellmann's fundamental classification is perhaps the best. He divides the forms into two great classes, the *columnar* and the *tabular*. No. 857 is a good example of the columnar; Nos. 716 and 746 illustrate the tabular, while No. 777 presents good examples of both. For convenience these two fundamental types may be divided into sub-varieties and the classification adopted by Scoresby and others may be used for this purpose.

The solid tabular forms will be denominated *lamellar*. (See Nos. 746 and 850.) The crystals of more or less open structure possessing solid tabular nuclei, for want of a better name, will be referred to as *stellar*. (See Nos. 709 and 731.) Those possessing centrally open structure and devoid of solid tabular nuclei, resembling ferns, are the *fern-stellar*. (See Nos. 842, 920, and 737.) The columnar forms connecting one or more tabular crystals are classified as *doublets* (see No. 561), the extremely long needle-shaped columnar forms (see Nos. 700 and 227) will be designated as *needle-shaped* or *needlar* (classified by Scoresby as *spicular*.) It is to be noted that there are other forms whose structures entitle them to be considered as distinct types, but they occur so rarely that excepting the granular forms they will not be considered in the following analysis. (For examples of granular-covered crystals, see Nos. 529, 700, 704, and 807.)

We have now to consider the relative frequency of the appearance of these various types, in both local and general storms; their occurrence and distribution throughout the various portions of great storms; their relation to various cloud strata, their occurrence during various degrees of cold, etc.

Table 4 gives approximately the relative frequency of occurrence of the various types within each quadrant of the general storms, and also of the local snowfalls of the winter of 1901-2.

TABLE 4.—Frequency of types of snow crystals in 53 general storms.

Storm segments.	Columnar.	Lamellar-solid crystals or solid tabular.	Stellar nuclei.	Fern-stellar.	Doublets.	Needle-shaped.	Granular.
N	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	1
E	3	2	1	1	0	1	0
SE	0	0	0	0	0	0	0
S	0	0	1	2	0	0	2
SW	2	1	3	7	1	1	9
W	1	3	7	7	3	0	6
NW	0	1	3	3	1	1	4
Total number	6	7	15	20	5	3	22
Forms from central region	6	5	7	9	3	6	12
Forms whose location is undetermined	4	8	13	10	0	1	13
Total number of forms from all portions of the 53 general storms	16	20	35	43	8	10	47
Fourteen local snowfalls	1	0	2	4	0	0	8
Total number for both local and general storms	17	20	37	47	8	10	55

\*14 of all these cases came from the central portions. †So in Mss.

It is to be regretted that the data regarding local storm types are not more extensive; but as weather maps were only available for the past winter (1901-2) it was thought best to construct tables for the data secured during this one winter.

A comparison of the relative frequency of occurrence of the

various types within local and general storms, as given in Table 4, reveals great differences. The preponderance of the branching open structure crystals and granular forms will be noted, and it may be added that such types actually form a larger percentage of the total mass of the crystals than is indicated by the figures of the preceding table.

Most of the earlier observers mention the doublets as occurring very rarely. This seems to be not true as regards our locality. I have observed them quite frequently. A number of instances have come under my own observation, where nearly the whole snowfall, for many hours together, consisted of such forms. Prof. James C. Shedd, of Colorado College, Colo., who made a study, during the winter of 1901-2, of the snow forms occurring at his locality, mentions finding doublets on two occasions during this winter.

The apparent connection between the temperature of the air and the frequency of the appearance of the various forms is plainly indicated in Table 5.

TABLE 5.

Temperature of storms.	No. of storms.	Columnar.	Solid lamellar.	Stellar.	Fern-like.	Doublets.	Needle-like.	Granular.
Medium cold storms, temperature +13° to +5° F.	21	15	13	11	9	3	2	13
Very cold storms, temperature +5 to -10°	5	8	18	21	19	4	3	9
Total occurrence of each type.	26	23	31	32	28	7	5	22

It is worth noting that during "cold" snowfalls the solid columnar and tabular forms appear in nearly equal numbers with the more open stellar and fern-like varieties, and considerably outnumber the granular forms.

A comparison of the frequency of occurrence of the forms during various milder temperatures is most interesting and instructive.

The results, as given in the preceding tables, arrived at by a study of the data secured during the four winters of 1898-99 to 1901-2, inclusive, in regard to the relative frequency of occurrences of the various types and the apparent connection between size and form and the air temperatures, agree in general with the results arrived at by many other meteorologists and observers, both in Europe and America, as set forth in the work *Schneekrystalle*, by Dr. G. Hellmann, Berlin, 1893.<sup>2</sup>

Doubtless the actual connection between forms and sizes of snow crystals and the temperature and density of the air is much more intimate than our present knowledge would indicate, because our studies are based on air temperatures at the earth's surface, instead of in the cloud strata where the snow crystals form. The temperature may often be mild at the earth's surface when the crystals are developing at high altitudes where the cold is intense, and such crystals should be classed with those deposited during extreme cold.

The frequency of the occurrence of each type within each cloud stratum, one above the other, is given in Table 6. This table gives only the results obtained during the past winter, and it will be noted that the cirrus and cirro-cumulus clouds have deposited no snow crystals. These clouds, when occurring alone, very rarely if ever deposit crystals of sufficient size to fall to the earth.

Table 6 gives but approximate results and may be sometimes misleading, because when nimbus or stratus clouds are present the existence of cloud strata lying above the lower clouds can not be certainly determined, but have been inferred from general considerations.

<sup>2</sup> G. Nordenskiöld. Preliminär meddelande rörande en undersökning snökrystaller. Af G. Nordenskiöld. Foren. i Stockholm Forhandl. Bd. 15. Haft 3. 1893. (Geol. Society of Sweden 146-158 und Tafel 5-26.)

TABLE 6.—General frequency of occurrence of the various types of snow crystals during 67 snowfalls in the winter of 1901-2.

Kind of clouds.	Total number of snowfalls from each cloud.	Columnar.	Solid lamellar.	Stellar.	Fern-like.	Doublets.	Needle-shaped.	Granular.	Totals.
Cumulo-nimbus	25	1	0	7	16	0	3	19	46
Stratus and nimbus	5	3	2	3	4	2	1	0	15
Cirro-stratus and nimbus	25	5	13	16	16	3	5	22	90
Cirro-Cumulus	0	0	0	0	0	0	0	0	0
Stratus	2	1	2	2	0	0	0	1	6
Cirrus	0	0	0	0	0	0	0	0	0
Cirrus	7	7	5	5	4	0	1	0	22
Cirrus-stratus	3	1	1	2	2	1	0	2	9
Cirrus and cumulus	3	1	1	2	2	1	0	2	9
Totals	67	18	23	35	42	6	10	44	178

In general the snow forms are most frequently precipitated when two or more cloud strata exist.

During great storms, especially whenever perfect forms are being produced, such as are portrayed in the following pages, the presence of two-cloud strata is almost always indicated; and much more frequently might these be inferred from Table 5, which gives cloud data for both local and miscellaneous snowfalls, rather than for great storms producing perfect forms.

## ANALYSIS OF CLOUD DATA.

It may be of interest to briefly describe the probable numbers and characters of the various cloud strata and the types associated with each. In general, there are present two great cloud divisions, lower and upper. The lower clouds are drifting spirally inward toward the storm's center; the upper clouds, which often extend outward far beyond the lower clouds and the area of precipitation, are drifting outward away from the storm center. Within the central regions of the storm, and also within detached portions of the outer regions, the ascension and horizontal expansion of the lower clouds form vast masses of intermediate and upper clouds. In the eastern and southern regions the upper clouds flowing outward, or more nearly with the average eastward drift of the whole atmosphere in our latitudes, naturally move fastest, and extend farther outward than do such clouds within the other segments of the storm. The relatively warm moist air flowing horizontally inward below these upper clouds, does not usually ascend in mass, until it approaches the storm's center; hence, the lower cloud strata within these segments are inconsiderable, consisting usually of but small detached masses of swiftly moving nimbus clouds. It may be assumed that these two widely separated strata will each sparingly shed the types of crystals that seem to be appropriate to each, i. e., the upper clouds will shed the small solid columnar or tabular forms; the lower clouds, the frail branching tabular crystals. It may also be assumed that near the center of the storm, these two varieties will reach a more complete development, and be of larger size and that other varieties (especially granular forms) will be associated with them.

Within the northern segments of a storm the relatively cold, inflowing lower air will be heavier, and will not exhibit as strong a tendency to ascend as do similar lower currents within other portions of the storm; hence, the production of snow crystals will usually be much less here than elsewhere. Probably a portion of the great mass of ascending and subsequently chilled air of the central portions of snowstorms flows outward and downward within the northern portion of the storm and forms a vast cloud, covering intermediate and other altitudes. These various horizontal cloud strata will, it is assumed, allow of the formation of a great variety of medium and small sized crystals of both the columnar and tabular varieties. Within this northern portion of the storm many of the crystals will probably undergo development while slowly drifting horizontally, or slowly descending.

The clouds within the western segment of the storm are not likely to differ greatly from the northern, except in so far as the lower ones exhibit a stronger tendency to ascend, and so far as overhanging upper clouds are sometimes absent. The great variety and vertical depth of the clouds within this segment will, however, conduce to the formation of a great variety of types, and to more complete development. Our data show that perfect forms are most commonly produced in this western segment of the general storm. I would suggest that possibly a partial explanation of this most interesting result of our work may be found in the fact that in this western segment of the storm the tendency of the lower clouds to ascend and the upper ones to descend, may somewhat neutralize each other, producing a calm within the intermediate cloud strata. This calm condition in the intermediate and upper air may be rendered more perfect, because in this segment the outflowing upper air and cloud strata tend to flow westward and meet, or oppose, the general eastward drift of the whole atmosphere in our latitudes.

We have now but to consider the central portions of general storms. We may conclude with much certainty that the convergence of large bodies of moist air, either warm or cold, causes its general, and often violent, ascension at the center. The ascent of this body of vapor laden air around the storm center, especially in its southwest and central portions, causes the formation of immense continuous cloud masses, reaching from the lower clouds up to, and merging into and forming, both intermediate and upper strata. These great ascending cloud masses allow of the formation of nearly or quite all of the various types of crystals. The moist low clouds and the state of violent agitation conduce to the formation of imperfect crystals and granular forms, and to the fractures of the crystals.

#### STRUCTURE OF SNOW CRYSTALS.

The beautiful details, the lines, rods, flowery geometrical tracings and delicate symmetrically arranged shadings to be found within the interior portions of most of the more compact tabular crystals, and in less degree within the more open ones, have attracted the attention of nearly all observers who have studied snow crystals. That these interior details more or less perfectly outline preexisting forms must have been early recognized, yet the knowledge as to what they actually were remained long in obscurity, and a complete explanation of all of them is yet to be found. The investigations of Dr. Nordenskiöld and G. Hellmann enable us to form a general conception as to their true character. These observers discovered that many of the lines, rods, and other configurations within the crystals, that add so much to the beauty of the forms, and which are so plainly revealed in the photomicrographs, are due to minute inclusions of air. This included air prevents a complete joining of the water molecules; the walls of the resultant air tubes cause the absorption and refraction of a part of the rays of light entering the crystal; hence, those portions appear darker by transmitted light than do the other portions. The softer and broader interior shadings may perhaps also be due, in whole or part, to the same cause, but if so, the corresponding inclusions of air must necessarily be much more attenuated and more widely diffused than in the former cases. We can only conjecture as to the manner in which these minute air tubes and blisters are formed. It may well be that some of them are the result of a sudden and simultaneous rushing together of water molecules around the crystal from all sides. This might result in the formation of closely contiguous parallel ledges, or laterally projecting outgrowths that are separated from each other during the initial impact by a narrow groove, or air space, but are soon bridged over by subsequent growth. Similar contiguous parallel growths occur frequently around the angles of very short col-

umnar forms, and lend plausibility to this theory. Air spaces also exist within columnar forms, as noted by Hellmann and Nordenskiöld. They seem to occur within such forms as hollow cup-like extensions, projecting perpendicularly within them from each of the ends of the crystals. Their presence is strongly indicated in some of the photomicrographs of such forms illustrating this article. (See Nos. 777 and 857.)

#### MODIFICATIONS OF FORMS OF SNOW CRYSTALS.

We now pass on to the study of the modifications that the typical forms undergo during their growth within the clouds. This aspect of our study is peculiarly fascinating.

I assume that the configurations of the exterior portions of the crystals surrounding the nucleus must depend largely upon the initial and subsequent movement, or the flights, upward, downward, or horizontally, of the growing crystals within the clouds. We must therefore make a careful study and analysis of the interior portions of the crystals, including the rods, dots, and lines outlining geometrical forms, that add so much to their beauty and interest. These interior details reveal more or less completely the preexisting forms that the crystals assumed during their youth in cloudland. Was ever life history written in more dainty or fairy-like hieroglyphics? How charming the task of trying to decipher them.

By close study of the photomicrographs, we find that the most common forms outlined within the nuclear portions of the crystals is a simple star of six rays, a solid hexagon, and a circle. The subsequent additions assume a bewildering variety of shapes, each of which usually differs widely from the one that preceded it, and from the primitive nuclear form at its center. Bearing in mind, however, the tendency of the crystals evolved within the upper clouds toward solidity, and the tendency of those from the lower clouds to form more branching open crystals, our task of deciphering the hieroglyphics, and of tracing thereby the probable flights of each individual crystal within the clouds, becomes much easier than might be anticipated.

Taking photomicrograph No. 821 as an example, we can picture with some certainty its various flights within the clouds during each stage of its growth. Star shaped at birth, it was probably carried upward by ascending air currents, and at some upper level assumed the solid hexagonal form that we see outlined around the star shaped nucleus. Having now become heavier, it probably descended, and acquired further growth at some lower level, such as that wherein it had its birth.

No. 831 tells a different story. If we may judge of its life history, as written within its face, it originated at a high altitude and completed its growth wholly at low levels.

Conversely, Nos. 920 and 850 each consummated the whole of its development within one cloud stratum, No. 920 in the lower and No. 850 in the upper clouds. In short, if the nuclear portion is surrounded by outline details indicating branch-like development, we assume that it acquired its branching additions at lower levels and consequently must have descended shortly after birth. Conversely, if the nucleus is surrounded by such details as constitute solid or compact additions, we may assume that it acquired these additions after being wafted upward into regions much higher in altitude than were those wherein its birth took place.

#### MODIFICATIONS OF FORMS DUE TO OTHER CAUSES.

As it is generally conceded that winds play an important part in modifying the forms of snow crystals, let us consider the probable manner in which they operate to accomplish this.

Aside from causing modifications by wafting the crystals upward and downward within the clouds to regions varying in temperature, humidity, density, etc., as previously noted,

the winds probably cause modifications in other ways. Violent winds may prevent a perfect and orderly joining of the aqueous molecules, causing imperfections in the forms, or perhaps amorphous, granular aggregations.

Again, they may waft greater quantities of water molecules to one or more portions of a growing crystal, causing abnormal growth to take place around such portions.

More important still, violent winds often cause fractures to occur, especially as regards the branching forms and whenever, as must often happen, subsequent growth takes place around and upon such broken crystals, irregular, unsymmetrical forms result. Doubtless, we may attribute the origin of some of the odd oblong crystals (see No. 565) to the fact that crystallization sometimes takes place around and upon a long broken branch, or other long portion detached by fracture from some preexisting crystal. Other odd forms seem to owe their abnormal character to design rather than accident. Columnar forms and, in a less degree, small solid tabular forms, being relatively so much heavier and more compact than stellar and similar branching forms, are much less likely than these to be wafted about and to receive modifications due to wind action.

Among the other causes of modification of forms, we must mention the close proximity of two or more crystals during one or more stages of their growth. This close proximity while developing, would probably cause a greater growth of those portions of each contiguous crystal that lie farthest away from the crystal closely adjoining, and thus perfect symmetry would be impaired.

Considerable modifications of form are frequently due to the aggregation upon the crystals of amorphous or granular material, contributed by relatively coarse cloud spherules, particles of mist, or minute rain drops. Frail light, branching stellar and other forms are often rendered coarse and heavy by such additions taking place around and upon every angle of the crystals, so that they fall quickly to the earth.

Perfect crystals are frequently covered over and lines of beauty obliterated by such granular coatings. Granulation often proceeds to such a degree, and the true crystals are so deeply coated over and imbedded within it, that the character of the nucleus does not reveal itself, except under the closest examination. Such heavy granular covered crystals possess great interest for many reasons; they show when the character of the snow is due to the aggregation of relatively coarse cloud particles, or minute rain drops and not to the aggregation of the much smaller molecules of water, presumably floating freely about between them. They also offer a complete explanation of the formation and growth of the very large rain drops that often fall from thunderclouds and other rainstorms, if we accept the conclusion that such large drops result from the melting, or merging together of one or more of the large granular crystals. For many reasons (among which we mention the almost invariable presence of low cloud strata when granulation occurs, and the aggregation occurring on perfect crystals, while these are presumably within the low clouds, rather than the occurrence of such aggregations as a distinct identity by itself) we are led to infer that, as a rule, the heavy granular covered crystals are peculiarly a product of the lower or intermediate cloud strata.

The dependence of the granular forms upon the presence of the lower clouds, will be readily seen by consulting Table 5, showing cloud formation in connection with the occurrence of the various types of snow crystals. While most granular forms possess true crystalline nuclei, there is reason to suppose that they sometimes form directly from the particles of cloud or mist.

PROBABLE CHARACTER OF THE MATERIAL, AND MANNER OF JOINING THE MOLECULES OF WATER DURING THE FORMATION OF THE CRYSTALS.

This interesting department of our study is necessarily and

largely suggestive in character, as no one has yet or, indeed, ever can actually see the extremely minute water particles rush together and form themselves into snow crystals. While it is true, in general, that snow crystals form within the clouds, yet it does not by any means necessarily follow that the true crystals are built up by the aggregation of relatively coarse cloud particles. Clouds form whenever the air is overcharged with moisture, and often exist for days and weeks together without depositing snow or rain. The individual particles of these clouds are probably frozen into the semblance of crystals when they experience the intense cold of the upper air. The cloud laden air currents that flow upward and outward within and around our great storms, plainly suggest that clouds are the dross or the unavailable waste of crystal building rather than the actual material out of which the true crystals are formed. We seem to have good grounds for assuming that the true snow crystals are formed directly from the minute invisible atoms or molecules of water in the air, without first assuming a coarse, intermediate state as cloud material. While it may be granted that possibly such relatively coarse cloud particles may possess attractive properties for one another strong enough to cause them to unite, yet it seems somewhat doubtful whether even this union could be accomplished in a manner so complete as to leave no trace behind in the interior structure of the crystals when such are examined under powerful microscopes.

The particles forming granular snow may be much larger than the common cloud particles, but may still be compared with them. When these unite together the dotted, stippled appearance of the resulting crystals denotes unerringly the imperfect joining of such particles and the noncrystalline character of the compound crystal. Cloud particles, while very minute, are yet individually visible to the naked eye when viewed under favorable conditions, appearing as a fine, dusty mass. As bearing upon this point, it may be noted that the crystallization of a mineral in solution, such as alum or salt-petre in water, is not first preceded by the aggregation of its molecules into a coarse intermediate cloud-like state, but is accomplished by the direct aggregation of the ultimate molecules of the substance.

#### CHRONOLOGICAL LIST OF SNOWSTORMS AND PHOTOMICROGRAPHS.

We now pass to the analysis of the photomicrographs of individual snow crystals secured during the remarkably favorable winter of 1901-2. The number of individual crystals is very considerable, and the beautiful or odd and interesting ones form a large percentage of the whole number; many of them deserve special mention and prolonged close study. Considering them in chronological order, the snow forms of the late November blizzards first demand our attention. Many interesting and beautiful crystals were observed on November 25, 26, 27, 28, and 30. (See Nos. 700 to 737.) It is very rare, indeed, that perfect forms occur during so many consecutive days.

#### 1901.

*November 25.*—Photomicrographs Nos. 700-703 are examples of long columnar forms, some slightly granular, called in Scoresby's classification "spiculae." No. 702 presents one of the oddest and most remarkable crystals ever photographed. By some extraordinary combination of circumstances, occurring during the latter stages of its growth, the aqueous material of which it was built was apparently brought to it from one direction only, thus greatly augmenting the growth of all parts of the crystal facing in that direction. The general weather conditions and the serial numbers of the photographs of types of crystals are given in Table 1. The center of the storm was over Halifax, Nova Scotia, and the central-western portion was over our locality. The predominant types of crys-

tals were long needle-shaped columnar forms, associated with granular covered tabular forms. Stratus clouds and low detached nimbus covered the sky and the higher cirro-stratus were probably superimposed on them.<sup>3</sup>

*November 26.*—Continuation of the same storm. Crystal types mostly tabular, both solid and branching, associated sometimes with doublets; in general the crystals were of large size and open structure. The central-western portion of the storm was still over our location, and as the day advanced and the cold increased, the crystals became progressively more and more compact in structure. Some eighteen different forms, 704–721, were photographed on this date and among them, two, Nos. 716 and 718, are very choice and beautiful. These exhibit a rather unusual and notable peculiarity, viz, a plain or delicately lined nucleus contrasted with a brecciated, boldly designed external portion; the latter approaching granulation, as though the nuclear portion was formed in clouds that were less dense and humid than those in which the outline portions were added. No. 712 is a fine example of the star shaped form of crystal, exhibiting an extreme and slender development of the six primary rays without any corresponding development of the secondary rays. Many of the branching forms of this date were observed to be broken as though by the action of violent winds.

*November 27.*—Continuation of the same storm. Photomicrographs Nos. 722–726. Crystal types small, granular, and irregular, succeeded later by medium sized, rather compact crystalline tabular forms and a few doublets. Nos. 722 and 723 are charming patterns in snow architecture. The crystals of this date dropped from the clouds of the western edge of the preceding prolonged storm of the 25th and 26th.

*November 28.*—Rather thin stratus clouds lying above thin detached nimbus masses. These last belated cloud legions of the storm of November 25, 26, and 27 furnished a few small but perfect snow crystals. (See Nos. 727–729.)

*November 30.*—Clouds rather thin stratus and nimbus. Crystal types wholly tabular of both open and stellate structure. (See Nos. 730–737.)

Among the seven forms of this date we find much to admire in the perfect beauty and symmetry of Nos. 731–734. The beautiful starfish design exhibited by No. 735 is somewhat rare. It is noteworthy that Prof. S. Squinabol, of the University of Padua, made drawings of a snow crystal found in Genoa in 1887 that closely resembles this latter one. The star with long slender rays deposited during this same storm, on November 26 (see No. 712), also closely resembles one (No. 4) figured by Squinabol in his work *La Navigata*. No. 737 is another form that closely resembles some of those secured by other observers; it is very similar to some of the photomicrographs secured by Dr. Neuhaus, of Berlin, during the winter of 1893, and published in Dr. G. Hellman's work.

*December 4.*—Clouds stratus, with detached running masses of low nimbus; probably high cirro-stratus above these. The western portion of this cold southern storm passed over our locality and furnished a great number of forms of snow crystals that were in general rather small and compact; as will be seen by consulting the photomicrographs Nos. 738–765, many of them are rarely beautiful and symmetrical. The snows of this storm exhibited great variety; solid and branching tabular forms, doublets, and columnar forms were each plentiful.

The rare beauty of Nos. 745, 748, 758 will appeal to all; crystallographers will find much of interest in Nos. 740, 749, 752, 754. One can but wonder how No. 740 acquired its two abnormally large points, and No. 752 its strange addition projecting perpendicularly. This singular addition, an exact

counterpart of one-half of the basal tabular crystal upon which it rests and from which it projects nearly perpendicularly, shows but imperfectly in the photomicrograph as a dark, broad, shadowy line stretching centrally across its greatest length. Perhaps the most remarkable thing about this projecting addition is its deviation from the perpendicular. No. 562½, of January 31, 1901, portrays a rare crystal, possessing two vertical additions projecting in opposite directions.

*December 5.*—Thin nimbus clouds on the west edge of the storm afforded minute granular crystals and solid frost-like tabular types. No. 766, secured during the forenoon, is the only photomicrograph taken on this date.

*December 15.*—Clouds stratus and nimbus, probably upper cirro-stratus above them. This storm afforded a few perfect snow forms and many unusual odd forms. (See Nos. 767–774.) The attachment to No. 769, like a bay window, deserves especial study, and we can but wonder whether this singular addition was the result of the merging together of two distinct forms. The germ crystals and needle-like forms depicted in No. 767 are worthy of study. The general character of the crystals of December 15 is best expressed by the word *diversified*, as columnar and needle-shaped forms, solid and branching tabular forms, and doublets were at one time or other present in the snowfall. Many of the doublets were connected by an extremely long slender columnar form. The snowfall was preceded in the early morning by rain and hail, and relatively high temperature.

*December 25.*—Dense stratus clouds, with detached masses of low nimbus; probably cirro-stratus above them. The west-central portion of the widespread storm of this date furnished a great variety of snow types, among which we find many most interesting forms. (See Nos. 775–779.) Although lacking in beauty (except No. 779), they are of great value to the crystallographer and student. We wonder how No. 775 came to acquire its three abnormal points; they seem to be the result of design, not accident. No. 778 presents us with another crystallographic problem, even more difficult to solve. How came the triangular nucleus to gather around itself such peculiar and irregular additions? No. 776 is also most unusual. We can offer no explanation as to how the delicate, beautiful, and unique central details of No. 779 were acquired. No. 777 is, if possible of even more interest than the others. The beautiful and perfect columnar forms seen in this crystal exhibit unmistakable evidence of their previous hollow cylindrical character; the large cavities outlined plainly within each end seem to have been covered or bridged over with outline growth. G. Nordenskiöld and other observers have asserted that such cavities sometimes exist within columnar forms; this crystal gives a striking proof of the correctness of the earlier observations. Such large cavities, however, seem to be rather rare; this is the only example I have ever observed of one so large and so plainly indicated.

## 1902.

*January 1.*—The extremely cold and nearly cloudless skies furnished the very minute frost-like forms to be seen in No. 779½.

*January 5.*—The clouds of the western edge of the storm of January 5, 1902, furnished a large and splendid set of forms. The general character of the crystals is shown in the photomicrographs Nos. 780–797. Nos. 783, 785, 786, and 788 are exquisite examples of the frail, branching type of crystals, while Nos. 793, 794, and 795 are fine examples of more solid forms. No. 785 is so rarely beautiful that it is the peer of any in my whole collection. No. 796 exhibits the slight granular deposit that at times partly covered some of the forms, and No. 781, whose nucleus is wonderfully beautiful and perfect, exhibits irregularities in outline apparently due to a more rapid growth of the secondary rays from two of the main rays located opposite

<sup>3</sup>The forms of the snow crystals seem to show that they must have fallen from high cirro-stratus through the lower stratus to the ground, growing in complexity and size as they fell. When the upper clouds are hidden we may judge whether they were present by the nature of the snow crystals.

to each other. It is rare, indeed, that large, frail, branching forms come to us so symmetrical and unbroken, as did many of these. No. 792 of the series needs especial mention. By close inspection it will be seen that its nuclear portion was built outwardly by a succession of alternate abnormal growths taking place from opposite directions, as though by successive impacts of crystalline material, first upon one-half and then upon the opposite half of the growing crystal. The combination of circumstances conducing to such alternate and opposite outgrowths must indeed be remarkable. The almost perfect symmetry assumed by many of the frail, branching forms of this series greatly resembles in ideal perfection the beautiful drawings of the English observers, Scoresby and Glaisher, and leads us to think that, contrary to the conclusions reached by some recent observers, such drawings may be quite true to nature and more reliable than we have been led to suppose.

*January 10.*—Clouds cirro-stratus, stratus, and nimbus. The southwest portion of the storm of January 10 deposited a unique collection of forms. (See Nos. 798–808.) The forms were rather small and compact; many odd triangular forms and oblong crystals were interspersed among the more common columnar and compact tabular forms of this snowfall. No. 805, or the oblong one, with an addition projecting abnormally, is similar to No. 752 of December 4, 1901. (See that description.) No. 800 is another rare form. Nos. 801 and 808 are two charming examples showing triangular development. If we may judge by the interior nuclear figure of 801, it was at some period of its growth perfectly triangular in outline. No. 807 shows the granular deposit that collected upon the crystals during the late afternoon, after low nimbus clouds had thickly covered over the sky.

*January 12.*—Clouds obscured by heavy snowfall. A long series of magnificent snow crystals was secured from the clouds of the southwest-central portion of the storm or blizzard of January 12. (See Nos. 809–833.) The snow, as usual whenever it comes from the central-western portion of a storm, consisted of a great variety of types both columnar and tabular, but as the storm's central portion passed farther to the east, during the afternoon of January 12, the columnar forms ceased to be deposited. Nos. 811, 818, 821, 822, and 826 possess much beauty of design and perfection of form. No. 826 exhibits the delicate scalloped hexagonal-shaped design, which we assume to be not a preexisting outline form, but as produced by additions to and upon, but not around, the crystal after its development had proceeded beyond the scalloped addition. Nos. 815 and 833 show abnormalities on one-half of each of these forms that render them very interesting; in No. 812 we see an almost perfect imitation of many of the long tabular crystals of hoar frost. No. 828 is unique in design and is especially interesting by reason of the very minute dotted nuclear features.

*January 13.*—Stratus and nimbus clouds. Possibly high strata present during the forenoon. A continuation of the preceding storm furnished on this date the interesting set of forms, Nos. 834 to 838. The crystals were wholly of the tabular form with the exception of a few granular forms and were of medium size. The great beauty of No. 837, and the unique and choice design exhibited by No. 836, will appeal to all lovers of the beautiful. The relatively intense degree of cold prevailing while these were formed is worthy of note.

*January 19.*—Clouds low nimbus; possibly thin stratus above them. The low lying clouds of the western portion of the rather small storm of January 19 deposited the charming examples of the frail, branching forms seen in Nos. 839–842. No. 842 represents quite correctly the general character and outlines of these types from low clouds; during relatively mild temperatures they are common to the low clouds of both local and general storms. Some of these forms bear a striking re-

semblance to certain of the photomicrographs of snow crystals secured by Herr A. A. Sigson in Rybinsk-Russia during the winter of 1894.<sup>4</sup>

*January 21.*—Clouds high cirro-stratus and thin detached nimbus. The southwestern portion of the storm of this date, accompanied by strong southeast winds, furnished the photomicrographs numbered 843–848. No. 845 shows a perfect symmetry and beauty. Nos. 844, 847, and 848 are chiefly valuable on account of their oddity. The broken, irregular contour of No. 844 tells eloquently of the severe winds it encountered somewhere during its flight from cloud to earth. The nuclear portion of No. 848 bears evidence of fractures and subsequent recrystallizations. No. 843 exhibits forms that presumably originated within the upper cirro-stratus clouds that covered the sky during this snowfall. Some of these crystals approach as near to the pyramidal form, which Scoresby asserts he saw on one occasion, as do any I have ever observed or photographed.

*February 7.*—Clouds cirro-stratus, a few nimbus. This storm contributed Nos. 849–856, including a few choice forms, of which Nos. 850, 854, 855, and 853 are exquisitely beautiful. The acorn design exhibited by No. 854 is quite unique, and the interior details within its outlines are faultless. The germ crystal, shown in No. 849, quite correctly portrays the character of the first crystals that fell from the high cirro-stratus clouds of the southwest portion of this prolonged storm, before the presence of lower clouds enabled the crystals to undergo a more complete and complex development. In addition to those mentioned above, the broad, leaf-like additions to No. 851 are worthy of mention.

*February 8.*—Clouds stratus and nimbus; probably high cirro-stratus superimposed above them. A continuation of the storm of February 7 and its increase in rigor furnished the large and charming set of photomicrographs, Nos. 857–887. This set comprises more forms than were ever before secured by me from any one storm. They fell from the clouds of the southwestern portion of the storm. Both columnar and tabular forms were common throughout the snowfall. Nos. 857, 858, 860, and 861 are beautiful and very interesting examples of the columnar type of crystals; Nos. 862, 863, 864, 866, and 867 are beautiful examples of stellate, tabular forms which partly replaced the columnar forms as the storm progressed. The beautiful branching crystals, Nos. 881 and 883 portray, in general, the characters of the forms that successively replaced both the solid tabular and columnar forms, as the western edge of the storm came nearer. Among other numbers possessing rare interest is No. 859 which presents us with another example of a crystal possessing one small stunted point. No. 884 exhibits a most interesting phase of crystalline evolution; it is composed of four contiguous points, or rather portions, and two somewhat stunted portions, also similar to each other, but differing widely from the other four. No. 885 shows two overlapping additions to two of the points, thus rendering it of more than usual interest, and presenting us with another seemingly unsolvable problem in crystallography. The numerous small but often-recurring additions by which the crystals continue their growth during intense cold are strikingly exemplified in Nos. 864 and 867. For a somewhat brief time during the snowfall many forms similar to Nos. 872 and 873 were common; associated with these for a brief time were many examples of solid tabular forms, possessing radiating interior designs similar to Nos. 869 and 874. No. 875 is a fine example of the star shaped forms; it exhibits a rather extreme and slender development of each of the primary rays, similar to No. 712 of November 26, 1901. A phenomenon that has been quite frequently observed by me, but rarely if ever mentioned by other observers of snow forms, is the occurrence of colors

<sup>4</sup>See Hellmann in *Meteorologische Zeitschrift*. 1894. Vol. VIII, p. 281.

of red or green, or a combination of both, within the well-defined nuclear portions of certain tabular forms. These colors can usually be seen only by reflected light when the crystals are viewed obliquely from a certain angle; very rarely also they are seen by transmitted light. A number of the more solid tabular forms, comprising a part of the snowfall of February 8, exhibited these colors in a remarkable degree, some of them even by transmitted light. No. 859 is one of the latter; the red, green, and purplish hues were plainly discernible within its nuclear portion, while the focussing of the crystal was in progress. Other examples of individual crystals exhibiting this most interesting phenomenon are Nos. 863 and 866 of this series. The colors were confined to the light nuclear portion of No. 863, and to the light colored star-like rays emanating from it. As regards No. 866, the slightly dark plain portions, outlining a hexagonal figure immediately surrounding the delicate long-rayed nuclear star, were of a beautiful green color, when seen at a certain angle by reflected light. The colors seem to be the result of some peculiar arrangement of the aqueous molecules of the nucleus or central portion immediately contiguous thereto; they appear only in solid, or stellate tabular forms, i. e., those having a well-defined solid tabular nucleus, and are quite frequently met with in some snow falls while they are totally absent in others.<sup>5</sup>

Another interesting peculiarity pertaining to some of the forms of February 8 (and also to a few of those of other dates, see Nos. 837, 744, and 822) is the appearance within them of concentric circular lines or rings encircling the nuclear portion. A study of these curves was made by A. W. Waters<sup>6</sup> in 1877. He called them not inaptly meandering lines, ascribing their formation, doubtless correctly, to a partial melting of the forms by entering a relatively warm air current, and to subsequent recrystallization around the rounded partly melted angles or points of the crystals.

*February 10.*—Clouds low nimbus and rather thin stratus. (See photomicrographs Nos. 888–896.) The storm of the 7th and 8th continued during the 9th and until noon of the 10th, and furnished, from the clouds of its extreme western edge, many exquisite designs. (The forms collected on the 9th, presumably deposited from near the storm's center, were imperfect or covered with granular accretions.) Nos. 888–896 give ample proof of the beautiful designs of the crystals from this portion of the storm. In addition to the exceptional beauty of the intricate design of No. 890 it exhibits such remarkable symmetry in its arrangement that it is entitled to rank with the finest of this and other winters.

It is worthy that many of the forms are filled in with a multitude of internal details and the coincidence of this feature with relatively low temperatures is once more established.

*February 13.*—Clouds high cirro-stratus. Photomicrographs Nos. 897–900. This snowstorm was accompanied by low temperatures and evolved the characteristic cold weather types of crystals, i. e., solid columnar and solid tabular forms. Examples of the latter are shown in Nos. 897–900. No. 900 is a charming example of the solid tabular type.

*February 17.*—Clouds high cirro-stratus, also low clouds during latter part of day. Photomicrographs Nos. 901–905. The high cirro-stratus clouds, accompanied by low temperature, that marked the beginning of the storm of February 17 and 18 furnished the usual small, compact, solid columnar and solid tabular forms so common with each. The rapid rise in temperature, and the subsequent formation of lower cloud strata as the storm center approached our location, caused a gradual progressive metamorphism in the character of the forms. Nos. 901 and 902 are typical of forms evolved near the storm's northeast edge, while Nos. 903 and 904 exhibit those

prevailing during the afternoon of February 17. No. 904 is very beautiful. No. 903, which is but a central section of a crystal, portrays the perfection of the nucleus contrasted with the broken unsymmetrical exterior portions of the crystal, a peculiarity common to many of this date.

*February 18.*—Clouds unknown. Photomicrographs 906–922. A continuation of the storm of February 17 brought the central-western portion of this storm over our locality and the somewhat dense clouds of this portion of the storm furnished a large and charming set of forms. The forms, mainly tabular, exhibited both close and open structures, as shown by Nos. 910 and 920, respectively. There were many twin crystals in the early morning, similar to No. 19. No. 920 is exquisitely beautiful in outline, surpassed by few, if any, in our whole collection.

*February 19.*—Clouds were low nimbus, probably higher stratus present during the early part of the day. In the morning the crystals were small granular balls; these were succeeded by small granular somewhat solid tabular crystals; these in turn were followed by tabular forms free from granulation; during the afternoon the tabular forms of closer structure were replaced by crystals of open structure. As the last belated cloud legions of the prolonged storm of February 17 and 18 were passing overhead, during the forenoon of February 19, they contributed a few more choice examples of snow crystal architecture, as souvenirs of the skill of the Divine Artist, and these may be seen in Nos. 923–933. The design within the interior of No. 929 is unique and choice.

Columnar forms were missing among the snows of this portion of the storm, but granular snowballs (roundish granular snow) were somewhat common.

*March 19.*—With the storm of March 19, the snow crystal season of 1902 closed, yet even this belated storm furnished its quota of new and choice designs. (See Nos. 934–938.) The bold but graceful design exhibited by No. 935 is well worth study; the perfect symmetry of Nos. 936 and 937 appeals to our artistic sense and causes the eye to linger long upon them. The clouds on this date consisted mainly of cirro-stratus and stratus; detached low nimbus also present, sometimes thinly, at other times thickly, except during the early morning. The photomicrographs show various types of snow crystals; in the morning minute columnar and frost-like forms predominated; during the day tabular forms predominated, but there were at times doublets and long needle-shaped forms with some granular forms. Doublets were connected by extremely long columnar bars. In the afternoon large open fern and stellar forms appeared.

In concluding this mention of individual forms, it is worthy of note that, as during previous winters, occasionally single individual crystals, and more rarely larger numbers of such, produced during the storms of this winter, resembled closely, in outline or interior details, or oddity, one or more of the individual forms found among the snows of previous winters. The recurrence of similar types, after perhaps long intervals of time have elapsed, is a phenomenon of great interest.

In conclusion, it may be worth noting that by the addition of over 200 plates during the past winter, the number of individual photomicrographs of crystals in our collection is brought up to somewhat over 1,000, no two of which are alike. This completes also our seventeenth year of photographic work among the snow crystals.

In view of this large collection, each individual crystal of which varies in one or many particulars from any other, the question now naturally arises: Is there no limit to the number of distinct forms, or may we assume that, if our study be sufficiently prolonged, there will come a time when new patterns will rarely or never be found, most of the designs

<sup>5</sup> This must be an illustration of the colors of thin plates.—C. A.

<sup>6</sup> See Hellmann Schneekristalle, p. 59.

being merely reproductions or duplicates of those already photographed? A partial answer to this query seems to be indicated by the vast number of new patterns that were obtained from the past winter's storms, greater than any previous single winter has furnished. This fact, coupled with the certainty that the number of individual crystals that go to form the snowfall of even one storm, is so vast that one, or many observers, may never hope to find and see anything more than an absolutely insignificant fraction of the whole, leads us to the conclusion that, during all future time and so long as there shall be observers to search for them, new designs will continue to be found to delight the eye with their beauty.

Another interesting thought that arises is: That it is extremely improbable that anyone has as yet found, or, indeed,

ever will find, the one preeminently beautiful and symmetrical snow crystal that nature has probably fashioned when in her most artistic mood.

In closing, it seems hardly necessary to add that this most charming and delightful branch of nature study is as yet at its beginning; it still possesses the charm of novelty; many of its problems are unsolved, and many will find its pursuit a source of great pleasure and instruction.

#### CORRIGENDA.

On page 397 of the MONTHLY WEATHER REVIEW for August, 1902, below the title of the article on "Ocean Currents," insert "Reprinted with slight changes, from pages 135-142 of the National Geographical Magazine.

### REPORT OF THE CHIEF OF THE WEATHER BUREAU FOR THE FISCAL YEAR ENDING JUNE 30, 1902.

Dated October 15, 1902.

I have the honor to submit a report of the operations of the Weather Bureau during the fiscal year that ended June 30, 1902.

#### FORECASTS AND WARNINGS.

The most important tropical storm of the year appeared first as a feeble disturbance in the subtropical region north of Cuba August 9, 1901. It advanced thence over the southern part of the Florida Peninsula during the 10th and 11th, and recurved westward over the Gulf of Mexico by the morning of the 12th. Moving westward the storm increased greatly in intensity during the 13th and 14th, and during the 14th and 15th it recurved northward over the Louisiana coast, attended by gales of hurricane force. Warnings in connection with this storm were begun on the 10th. The estimated damage to property along the Louisiana coast amounted to over \$1,000,000, and according to the estimate of the secretary of the Mobile Chamber of Commerce the value of property saved by the warnings of the Weather Bureau aggregated several millions of dollars.

The North Atlantic and West Indian forecast and storm-warning service was continued in successful operation during the year. Forecasts, for the first three days out, for the use of steamers bound for European ports were issued daily at 8 a. m. and 8 p. m.; American and European shipping interests were notified of the character and probable course of the more severe storms that passed eastward from the American coast.

The following letter, dated November 15, 1901, addressed by the secretary of Lloyd's, London, to the Chief of the United States Weather Bureau, at Washington, indicates the degree of interest that is being taken in the Weather Bureau warnings by representatives of the commercial and shipping interests of the North Atlantic:

I am instructed to express to you the best thanks of the committee of Lloyd's for the forecasts of bad weather in the Atlantic with which you have been so good as to allow them to be favored, and I am desired to convey to you the congratulations of my committee on the infallibility of the predictions that have been supplied by these forecasts.

On the morning of November 1, 1901, the following message was telegraphed to the Weather Bureau offices at Hamilton, Bermuda; New York, N. Y.; Philadelphia, Pa.; and Boston, Mass.: "Severe disturbance moving northward east of Turks Island will probably pass near Bermuda Saturday."

The following article from the Bermuda Colonist of November 6, 1901, verifies the accuracy of the advices furnished:

The hurricane that was predicted by the Washington Weather Bureau for Saturday arrived on time and raged around the islands for twenty-four hours. All the incoming steamers were delayed in consequence, and those that were southward bound, the New York mail steamers especially, experienced exceedingly heavy weather. The growing crops throughout

the colony have suffered somewhat, and the storm damage to property has been considerable. The principal damage reported has been occasioned to government property about the islands in the Great Sound, where the prisoners of war are interned, and it is said that the preliminary estimate of the damage reaches the sum of £2000. Reports from the westward state that the contractors for the dock-yard extension works have also sustained some loss; a large boat used for conveying laborers and a large quantity of balk timber got adrift.

The first general frost-bearing cool wave of the fall of 1901 swept from the northeastern Rocky Mountain slope southward to Arkansas and Tennessee and eastward to the North Atlantic coast States, during September 17-20. Ample warnings were distributed throughout the districts visited by the frosts of the period referred to.

The cold waves of December, 1901, were exceptionally severe in the Lake region, the central valleys, and the Southern States. The following are among press comments made regarding these cold waves:

The cold-wave warning was issued fully thirty-six hours in advance of the cold changes; it was telegraphed to all the important towns of the State, from which points it was distributed by mail. It is learned that the information was posted in over 1500 places in the State yesterday morning, which demonstrates the very thorough and rapid system the Weather Bureau now has for getting such warnings before those who are actually interested.—*Montgomery (Ala.) Advertiser of December 10, 1901.*

There has been some injury in the citrus-fruit and winter-vegetable districts, but, thanks to the early warnings of the Weather Bureau, those who know how to burn and smoke as a preventive from frost effects saved much property and gave a new demonstration of the efficacy of the protective measures which have been brought to high development in California.—*Pacific Rural Press, San Francisco, December 17, 1901.*

The Weather Bureau gave ample notice of the coming of the cold wave, and its predictions have seldom been more accurate as to the extent of the wave, the territory that would be affected by it, and the degree of cold the thermometer would record; and this warning did much to prevent any serious damage to the cane crop from the freeze by giving the planters time to prepare for it.—*New Orleans Times-Democrat, December 17, 1901, editorial.*

Much credit is due the Pittsburg station of the United States Weather Bureau for its truthful and timely predictions in the recent sudden changes of weather in this section. Warnings far in advance of the first local intimation of a cold snap were sent to shippers of perishable goods, and thus much damage was averted that otherwise would have resulted. When the continuous rains and heavy snows set in, warnings were also sent out notifying property holders of the imminent danger of a flood.—*Pittsburg Post, December 16, 1901, editorial.*

The following warnings, telegraphed from Washington to Jacksonville for distribution in Florida, resulted in the protection of more than \$1,000,000 worth of fruit, vegetables, and other property, and a direct saving of \$540,000:

WASHINGTON, D. C., December, 19, 1901.

Center of low moving rapidly southeastward over Gulf. Minimum temperature to-night in central and north Florida will equal last night, and outlook is for lower temperature Friday night. All precautions against damage by cold justified for next two nights.

WASHINGTON, D. C., December 30, 1901.

Temperature will fall to about 20° at Jacksonville to-night, with temperature below freezing in the interior as far south as Jupiter. Emergency warnings, and notify postmasters.

The floods of the upper Ohio River in December, 1901, are referred to by the Pittsburg Gazette, of December 16, 1901, as follows:

The disaster to a large fleet of coal boats on the river last night is shown to be not chargeable to the weather service, which sent early warning of the coming of the high waters.

The destructive floods in the Appalachian Mountain streams during the closing days of February, 1902, were anticipated by the following warning, telegraphed February 23 from Washington to Weather Bureau stations in Pennsylvania and West Virginia for distribution:

Warmer weather indicated for the next two days, with conditions favorable for rain by Monday night. These conditions will be most favorable for a general breaking up of ice in the mountain rivers and streams of Pennsylvania, western Maryland, and West Virginia. Notify all interests concerned that danger from flood in low-lying land is imminent.

## DISTRIBUTION OF FORECASTS AND SPECIAL WARNINGS.

Much attention has been given to the mail distribution of daily forecasts through the rural free delivery, and a substantial increase was made in this direction, although during the latter part of the year our efforts were greatly hampered by lack of funds for the purchase of the necessary supplies for carrying on this important work.

State or Territory.	At Government expense.			Without expense to the United States by—					
	Daily forecasts.	Special warning only.	Emergency warning.	Mail, daily.	Rural free delivery, daily.	Railway telegraph service, daily.	Railway train service, daily.	Daily forecasts.	Special warning.
Alabama.....	29	6	152	900	857	31	12	15	28
Arizona.....	3	1	0	0	0	0	0	4	4
Arkansas.....	27	7	118	528	236	6	0	72	75
California.....	113	13	0	2,359	2,090	356	0	150	186
Colorado.....	19	17	81	359	1,201	2	7	4	23
Connecticut.....	14	4	52	979	2,225	12	151	3	0
Delaware.....	10	0	23	73	890	30	0	0	0
Dist. of Columbia.....	0	0	0	1,478	0	0	0	13	0
Florida.....	27	113	95	891	0	96	0	41	117
Georgia.....	40	37	268	1,568	2,045	141	41	25	348
Idaho.....	13	1	0	478	101	0	17	0	8
Illinois.....	117	28	524	3,424	7,196	127	459	175	711
Indiana.....	124	9	242	1,978	5,856	43	287	38	84
Indian Territory.....	8	0	5	154	0	0	0	0	0
Iowa.....	155	32	480	1,917	10,842	12	0	451	542
Kansas.....	66	8	217	808	3,802	29	15	3	0
Kentucky.....	39	37	102	1,928	75	21	0	400	407
Louisiana.....	24	37	71	735	125	0	0	11	49
Maine.....	23	5	46	1,569	1,920	0	77	3	18
Maryland.....	29	7	89	1,523	1,619	129	0	11	38
Massachusetts.....	25	22	71	3,647	2,770	0	331	16	61
Michigan.....	110	30	443	4,980	4,847	459	457	43	295
Minnesota.....	57	16	217	1,802	2,062	5	0	534	564
Mississippi.....	29	10	75	639	0	16	0	42	82
Missouri.....	102	11	280	4,204	7,323	31	0	358	323
Montana.....	21	3	24	638	0	0	0	12	19
Nebraska.....	63	12	241	1,067	1,777	0	0	37	81
Nevada.....	3	0	0	148	0	0	0	0	0
New Hampshire.....	18	1	39	682	2,730	0	31	0	0
New Jersey.....	29	27	127	1,181	255	176	0	40	34
New Mexico.....	5	2	0	15	0	7	0	7	30
New York.....	127	58	497	6,986	9,811	333	168	339	941
North Carolina.....	59	19	214	994	395	1	16	36	59
North Dakota.....	13	12	104	16	150	0	0	0	0
Ohio.....	145	92	407	7,812	22,381	38	17	1,456	4,609
Oklahoma.....	9	2	15	172	0	0	0	0	0
Oregon.....	20	2	0	795	745	0	104	0	3
Pennsylvania.....	68	23	345	3,922	290	827	0	1,967	768
Rhode Island.....	4	0	13	102	250	0	28	0	4
South Carolina.....	33	5	125	1,106	513	36	23	16	240
South Dakota.....	40	31	111	684	400	0	0	70	232
Tennessee.....	43	10	395	1,577	1,100	31	2	81	120
Texas.....	57	68	278	1,479	2,933	159	0	396	407
Utah.....	16	60	0	204	340	0	0	3	17
Vermont.....	11	1	50	598	175	9	13	1	1
Virginia.....	39	9	109	1,540	228	63	98	1,158	1,230
Washington.....	24	2	0	721	916	0	29	3	3
West Virginia.....	21	11	74	1,194	7	37	25	21	44
Wisconsin.....	69	16	447	1,802	1,733	1	16	40	66
Wyoming.....	6	4	8	90	40	16	0	1	1
July 1, 1902.....	2,146	921	7,096	74,327	105,161	3,280	2,423	8,297	12,872
July 1, 1901.....	1,958	985	7,096	*110,102	.....	3,280	2,423	8,297	12,872
Changes.....	188	-64	0	.....	.....	.....	.....	.....	.....

\* Including rural free delivery.

The preceding table shows the geographic extent of this work, as well as the increase over the distribution of the previous year:

There were in operation August 1, 1902, 10,025 rural free delivery routes, serving approximately 1,000,000 families, of which but 105,000 families (about 10 per cent), served by about 1000 routes, could be furnished with the forecasts of the Weather Bureau from the funds available for that purpose.

The Post-Office Department estimates that there will be in operation by July 1, 1903, 15,000 routes serving approximately 1,500,000 families. With the necessary funds it would be possible to make the distribution of the daily forecast of the Weather Bureau coextensive with the rural free delivery itself. The distribution of forecasts by this means alone would require not less than 450,000,000 blank forms for the routes that will be in operation on July 1, 1903. The purchase of these forms, together with the necessary printing appliances and the employment of the assistance required, will cost, it is estimated, not less than \$100,000.

## EQUIPMENT AND INSPECTION OF VOLUNTARY STATIONS.

The inspection of voluntary stations was undertaken on a more extensive scale than in any previous year in the history of the Bureau, and for the first time an allowance for this purpose was made to each section, \$1940 having been apportioned among the several sections according to their needs. It became necessary, however, before the end of the year to cancel the authority to use the unexpended balances on account of the uncertainty of being able to continue the inspections under the conditions prescribed. All amounts not used, therefore, by May 15 were turned in to be applied to other purposes for which the Bureau had urgent need. Less than \$600 of the amount allotted for the inspection of stations was used; but with this comparatively small amount 268 stations were inspected, at an average cost of \$1.94 per station. The experience gained during the year in this line will prove of decided advantage in the following year, for which an increased allowance has been made and all of which will doubtless be expended.

While 230 new voluntary stations have been established, the total number at the close of the year was but little greater than at the end of the preceding year, as 209 stations were discontinued. Efforts have been mainly directed toward the improvement of the equipment and exposure of instruments at stations already established rather than toward an increase in the number of stations. A very gratifying improvement in the character of the observations has followed. There can be no doubt that the voluntary observers of the Bureau, as a rule, now more thoroughly understand their duty and perform the same with more painstaking care than ever before. A large number of thermometers of various makes have been replaced by the standard tested instruments of the Weather Bureau, and many rain gages not of the Weather Bureau pattern have been replaced by those corresponding to the regular station equipment. In the work of establishing new voluntary stations and improving the equipment of those already established there have been issued during the year 607 maximum thermometers, 388 minimum thermometers, 313 thermometer shelters, and about 200 rain gages.

## COTTON AND SUGAR AND RICE SERVICES.

Four cotton-region stations have been discontinued and 18 established, 7 of the new stations being placed in the important cotton fields of Texas. These new stations constitute a valuable addition to the cotton-region service. The increase is highly appreciated by those interested in cotton. The number of sugar and rice region stations remains unchanged, there being 8 such stations. The total number of cotton and sugar and rice stations at the close of the year was 148.

## CORN AND WHEAT SERVICE.

Two new stations were established and none discontinued, the total number being 133.

## CALIFORNIA FRUIT AND WHEAT SERVICE.

This service was inaugurated during the latter part of the previous year, at the close of which there were 8 stations. The period covered by the reports extends from June 1 to August 31. Before the resumption of the service for 1902, 12 new stations were established, the total number now reporting being 20. This service has proved very popular; it supplies information of much value to the fruit and wheat interests of California. Daily bulletins are issued by the official at San Francisco giving the maximum and minimum temperatures and rainfall for the series of stations, the bulletins being identical in character with those of the corn and wheat and cotton region services.

## CLIMATE AND CROP PUBLICATIONS.

The standard of the monthly section reports has been fully maintained, and in some instances improved. The value of these is now more fully recognized, and the demand for them is constantly increasing. These reports are issued with promptness, and it rarely occurs that a section bulletin is not issued before the close of the month succeeding that for which it forms the record.

The weekly climate and crop bulletins are in greater demand than at any previous time. No material change has been made in the form of the bulletins issued by the several sections. The editors of agricultural and commercial papers avail themselves largely of these bulletins.

Recognizing the importance of preserving the section publications in the most careful manner, nearly \$1500 was expended during the year in binding at each center a complete file of all the section reports issued by the several sections. We have now, therefore, at every climate and crop center, bound in substantial manner, a complete file of the reports of each and every section, so that every climate and crop-service section center is prepared to place at the disposal of inquirers detailed climate and crop information from every part of the United States.

## THE WEATHER SERVICE IN CUBA.

The work that the Weather Bureau has carried on in Cuba may be divided into two classes:

(1) The climate and crop service, which is concerned with Cuba alone.

(2) The storm-warning service, of which the observation stations in Cuba form only a part of the general system operated primarily for the benefit of the commerce of the Gulf and South Atlantic coasts and the West Indies.

The Cuban section of the climate and crop service of the Weather Bureau has been turned over to the secretary of agriculture of the Republic of Cuba. It consisted of 25 voluntary observation stations, each one of which was equipped with a set of thermometers, a rain gage, an instrument shelter, and the necessary forms for the rendering of reports; it had also 86 crop correspondents.

The voluntary observers and the crop correspondents reported to Havana and gave to the section director the data that enabled him to publish a monthly climatological report of the island and a weekly bulletin showing the condition of crops in the various provinces.

That portion of our storm-warning service located on the island of Cuba consists of an observatory at Havana, one at Cienfuegos, one at Puerto Principe, and one at Santiago. The protection of our own seaports on the Gulf and South Atlantic coasts against the approach of West Indian hurricanes renders

it desirable to have a few observation stations on the island of Cuba.

A mutually beneficial cooperation has been proposed, whereby the Republic of Cuba might be given the benefit of our extensive system of cable-reporting stations in return for the privilege of maintaining the four stations hereinbefore referred to.

In accordance with the request of the Cuban Government, the Weather Bureau is still making forecasts for the island and cabling them to all of the commercial ports of the Republic. These warnings can only be made by some official having daily access to the extensive system of observations collected by the United States Government from the islands and mainland around and about the Gulf of Mexico and the Caribbean Sea.

Observations taken only on the island of Cuba would not cover an area of sufficient extent to render possible the making of the most accurate warnings. The Weather Bureau has in its possession the necessary data on which the most reliable forecasts and warnings for Cuba can be made, and has been glad to render this service to the Cuban Government.

## THE MONTHLY WEATHER REVIEW.

The MONTHLY WEATHER REVIEW has been published as regularly as practicable, but the number for the month of April, 1902, was kept waiting in order to include therein an important memoir on "Rainfall and charts of rainfall," illustrated with a special edition of the relief map of the United States, furnished by the cooperation of the United States Geological Survey. The REVIEW for the month of May was also delayed for about two weeks in order to include therein a plate of the bolograph spectrum furnished by the kindness of Prof. S. P. Langley, Secretary of the Smithsonian Institution. The July REVIEW appeared on time.

As the MONTHLY WEATHER REVIEW continues to be recognized as an important medium for the diffusion of information relative to results of work in all branches of climatology and meteorology, no pains have been spared to make it a credit to the Government. The general appearance of the REVIEW has been improved by the introduction of new type and a quality of paper that allows the insertion of illustrations in the text, thereby diminishing the general cost of printing. At my request the Editor has prepared a brief statement of the articles most important to meteorological science that have appeared during the past year. Special mention is made of the following:

(1) Byron McFarland: "The thunderstorm—a new explanation of one of its phenomena." In this the author maintains that the descending mass of cool air accompanying the rain, by reason of its greater density and pressure, causes the sudden rise in the barometer that generally accompanies a thunderstorm.

(2) Marcel Brillouin: "Historical introduction to his collection of original memoirs on the general circulation of the atmosphere." This is an excellent critical review of important publications on the movements of the atmosphere. The author especially enforces the necessity of studying the atmosphere in connection with the real surface of the earth, and not the ideal uniform globe that is generally considered by mathematicians.

(3) Frank W. Very: "The solar constant." This is an admirable review of the present state of our knowledge of the amount of heat received by the atmosphere from the sun, and the amounts absorbed and radiated by the air. Professor Very also gives some fundamental suggestions as to the method of investigating this subject, which is so important to meteorology. This article has been very favorably noticed by European reviewers.

(4) H. H. Kimball: "Ice caves and frozen wells." This embodies the results of a personal examination of several cases in which ice is formed and preserved under ground. Mr. Kimball gives a satisfactory general explanation of the meteorological conditions necessary to this formation of ice, showing that, in general, caves, wells, and porous ground are cooled by the percolation of cold air to such an extent that the cold ground will freeze any water that may subsequently flow into it. He cites cases of stalactites and stalagmites of ice in deserted iron mines. Taken in connection with the exhaustive descriptive work by E. S. Balch, of Philadelphia, we have now a very satisfactory idea of the process by which ice caves, ice beds, and frozen wells are formed throughout the world, and the former hypotheses, especially that which referred them back to the Glacial age, must now be abandoned.

(5) H. H. Kimball: "The general circulation of the atmosphere, especially in the Arctic regions." In this memoir, which was a thesis for the degree of M. S., the author shows the great contrast between the theories of Ferrel, Oberbeck, and Helmholtz on the one hand, and those of Bigelow and Teisserenc de Bort on the other. He then collects and charts all available observations of the movements of the highest cirrus clouds in northern latitudes, and shows that they demonstrate the existence of a rather weak movement of the surface wind westward for latitudes north of 65°, with modifications introduced by the low barometric pressures in the North Atlantic and Bering Sea. It is probable that these modifications are appreciable, because in northern latitudes the cirri are low down, and above these there should be a stronger current from the west eastward.

(6) C. F. Marvin: "The measurement of sunshine and the preliminary examination of Ångström's pyrheliometer." This paper not only introduces Ångström's electric compensation pyrheliometer to the attention of American physicists, but shows how it can be best used to advance meteorological research. Three copies of this instrument have been purchased by the Weather Bureau and carefully compared before being intrusted to the hands of the respective observers. Professor Marvin's paper gives the results of these comparisons, from which it appears that the amount of heat received from the sun per minute, per square centimeter, by a surface normal to the solar rays and outside of the earth's atmosphere, is about 3.1 gram calories, and that measurements made at sea level are liable to an uncertainty of about 1 per cent.

(7) O. L. Fassig: "The westward movement of the daily barometric wave." This is a short article accompanied by important charts, showing that the principal features in the diurnal curve of local variations of barometric pressure move westward around the globe daily.

(8), (9) Mark S. W. Jefferson: "The reduction of records of rain gages." This article calls attention to the unsatisfactory condition of our knowledge of the distribution of rainfall. The author suggests certain modifications in the methods of preparing rainfall charts. As this subject is of the greatest interest in relation to agriculture, irrigation, engineering, and general meteorology, correspondence was invited on this subject. Professor Abbe prepared an extensive "symposium" on "Rainfall and charts of rainfall," which appeared as a supplement to the MONTHLY WEATHER REVIEW for April, 1902. In this symposium the latest rainfall charts by Prof. A. J. Henry, of the United States Weather Bureau, for the years 1871-1901, inclusive, and by Mr. Henry Gannett, of the United States Geological Survey, for the years 1871-1893, appeared, accompanied by a relief map of the United States, which must be studied in connection with the rainfall. The correspondence and extracts published in this symposium explain the methods of preparing rainfall charts, and show some of the errors of those who would apply hypothetical corrections for altitude, or would, from the presence of forests and lakes, infer a special increase of rainfall. The whole discussion emphasizes the extreme importance of a large increase in the number of our rainfall stations, in order that the Weather Bureau may satisfactorily respond to the general public demand for information as to rainfall and snowfall.

(10) Maxwell Hall: "The sun-spot period and the temperature and rainfall of Jamaica." In this paper the author shows that since 1883 there has been a close parallelism between the mean maximum temperatures at Kingston and the curve of sun-spot numbers. There is also some show of parallelism between this sun-spot curve and that of the general rainfall for Jamaica.

(11) A. Wolfer: In order to facilitate the study of solar relations Professor Abbe reprinted in the MONTHLY WEATHER REVIEW for November, 1901, the complete table of "Wolf's relative sun-spot numbers." This led to a correspondence with Prof. A. Wolfer, of Zurich, who stated that, as the successor to Professor Wolf, he had undertaken to revise the original series of sun-spot numbers and incorporate all newly discovered data. This revision was therefore published with some remarks by Wolfer in the MONTHLY WEATHER REVIEW for April, 1902, simultaneously with its publication in Switzerland. This constitutes a most welcome addition to our knowledge of sun-spot phenomena, and while, on the one hand, it will undoubtedly stimulate research into the relations between the sun and the earth, it will, on the other hand, serve to refute many erroneous hypotheses and bring us nearer to the truth.

(12) Albert Matthews: "Indian summer." This is the result of an exhaustive examination of the literature of England and America; the author shows that the term Indian summer first appears in 1794, at which time it was probably in general use throughout the United States. This memoir has excited very general commendation, coupled with expressions of surprise at finding that we know so little about the origin of the term and the reason for its adoption.

(13) S. P. Langley: "The Astrophysical Observatory of the Smithsonian Institution." In this article Professor Langley first describes his bolometer and his laborious, but successful, efforts to secure a bolograph made by automatic methods. The article is illustrated with a remarkably fine reproduction of Langley's original bolograph spectrum. The author calls attention to the important meteorological bearings of his studies with the bolometer. That, in fact, our seasonal weather changes and probably also the irregularities of climate from year to year are dependent upon the absorption of solar heat by the carbonic-acid gas and the aqueous vapor in the atmosphere. The absorption is greatest in Wash-

ington in August. Similar results have been attained with the actinometer of Crova at Montpellier, and, especially, by the visual observations of aqueous absorption lines in the spectrum, as conducted by L. E. Jewell at the Johns Hopkins University and published in 1896 in Bulletin 16 of the United States Weather Bureau. There can, therefore, no longer be any doubt that by means of these instruments meteorologists at sea level will be able to gage the average and the special absorptive powers of the atmosphere above them. The bolograph and actinometer must, therefore, form an important adjunct in every important meteorological observatory.

(14) F. H. Brandenburg, W. V. Brown, and Prof. E. B. Garriott: "On the classification and index of weather maps and weather types as an aid to forecasting." These three articles on this subject have shown practicable methods of obtaining an end that is greatly to be desired. Professor Garriott especially calls attention to the fact that types of formations and movements of the same general character, extending over periods of several days, are much more important than types of individual weather maps or weather conditions. It is to be hoped that the great importance of this subject will stimulate further efforts in this line, but they will hardly attain complete success unless they are carried out in sympathy with correct views of the general circulation of the atmosphere. It is this latter question that offers the fundamental difficulty in all weather forecasting, and especially in long-range forecasts. An article in the December REVIEW, "The physical basis of long-range forecasts," explains the general character and difficulties of the problem in popular language, and suggests an appropriate method of treating the general circulation of the atmosphere, as disturbed by the presence of land and water on this globe. But the most important work on this subject is that of Professor Bigelow mentioned below.

(15) Prof. F. H. Bigelow: "Studies on the statics and kinematics of the atmosphere of the United States."

Paper I. "A new barometric system for the United States, Canada, and the West Indies."

Paper II. "Methods of observing and discussing the motions of the atmosphere."

Paper III. "The observed circulation of the atmosphere in high and low areas."

Paper IV. "Review of Ferrel's and Oberbeck's theories of the local and general circulations."

Paper V. "Relations between the general circulation and the cyclones and anticyclones."

Paper VI. "Certain mathematical formulæ useful in meteorological discussions."

This series of papers, published in the MONTHLY WEATHER REVIEW for January-June, 1902, are important contributions. They constitute a complete summary of Professor Bigelow's researches into the physics of the earth's atmosphere and also give us a general idea of nearly all that has thus far been accomplished in this field of work. This study involves a knowledge of the conditions prevailing at and above ordinary cloud levels; therefore, the author has discussed the movements of the atmosphere, the formation of clouds, the temperatures and moistures observed by the highest balloon ascensions. He not only summarizes all the work that is published in detail in his International Cloud Report and his System of Barometry, but he prepares the way for a proper reduction of the observations of temperature, moisture, and wind made at Weather Bureau stations and for drawing daily weather maps for several successive levels in the atmosphere. He finds that with increasing altitude above 10,000 meters the rate of diminution of temperature steadily diminishes, but recognizes that the accurate measurement of the temperature of the air in the highest strata is a very difficult process, and that all efforts to secure reliable results deserve the hearty support of meteorologists.

Among the most important papers accepted but still awaiting publication in the MONTHLY WEATHER REVIEW are the two following:

(1) W. A. Bentley: "A report on photomicrographs of snow crystals secured during the winter of 1901-2." For twenty years Mr. Bentley has devoted himself to the study of snow crystals. His collection of photomicrographs taken in Jericho, Vt., surpasses the sum total of all that has been done by all others in the world, and must form the basis of all future study into the reasons for the great variety of forms that occur. It seems likely that each snowflake contains within itself traces of the processes that it has had to undergo in its journey from the clouds to the earth. Therefore the crystals should tell us of the atmospheric conditions in the regions whence they came. From this point of view it is evidently important to encourage Mr. Bentley in his labor of love. It is to be hoped that a physicist of sufficient ability may be found to associate himself with Mr. Bentley in this work and to carry it on to a successful conclusion.

(2) J. W. Sandström: "On the construction of isobaric charts." This memoir has been prepared under the general supervision of Prof. V. Bjerknes, of the University of Stockholm, and is believed to present important novelties in practical meteorology. Mr. Sandström has made special use of the splendid series of observations in the free air obtained by the Weather Bureau by means of the Marvin kite and meteorograph, during the summer of 1898. It seems likely that his studies, taken in connection with those of Professor Bigelow, will indicate the proper

method of utilizing daily records from kites and balloons as supplementary to observations of the clouds by means of the nephoscope. Mr. Sandström's memoir was written in German, and is now being translated by Professor Abbe for publication.

Professor Abbe states that his duties as dean of the scientific staff and editor of the MONTHLY WEATHER REVIEW have been greatly lightened by the valuable assistance of Mr. H. H. Kimball as assistant editor of the REVIEW.

The recent publication of the important "Lehrbuch der Meteorologie," by Prof. Dr. Julius Hann, of Vienna, marks an important epoch in the history of meteorology. It constitutes a fairly complete summary of the present condition of our knowledge in all branches of observational meteorology, with many valuable suggestions as to theories and explanations of the phenomena. Professor Abbe has continued the translation of this work as rapidly as other duties would permit; but it is a large undertaking and can not be finished within the coming year.

#### CARNEGIE INSTITUTION.

The establishment of the Carnegie Institution for research has led the trustees to address the Chief of the Weather Bureau a general request for suggestions as to what this institution can do for meteorology, and the board of research appointed by the Chief of Bureau has duly reported on the subject. The trustees of the Carnegie Institution have requested Professor Abbe to act as their general adviser on matter pertaining to meteorology. The Chief of Bureau's report to the trustees, as also that of Professor Abbe, takes very much the same view of the subject; that is, that the Carnegie Institution should occupy those fields of research that are outside of the official duties of other institutions, but should cooperate with them as far as possible.

#### AERIAL RESEARCH.

There has been inaugurated a programme of aerial research in the upper strata of the atmosphere. Professor Abbe has been given charge of this work, with the privilege of calling upon Professors Marvin, Bigelow, and others for assistance. The first duty in connection with this work has been to correspond with manufacturers of hydrogen and with instrument makers and special aeronautic experts in the United States and Europe, in order to ascertain what is at present considered practicable and best. There is every prospect that we shall be able to send up some sounding balloons with meteorographs during the coming year. Meanwhile the most laborious part of the preparatory work falls upon Professor Marvin and will take nearly all of his time for six months to come.

#### SOLAR HEAT AND ATMOSPHERIC ABSORPTION.

In July, 1901, the Bureau received three copies of Ångström's Electric Compensation Pyrheliometer, which instrument is intended to measure in calories the amount of heat received by radiation from any distant source, including, of course, the sun. It is intended to use these three instruments in carrying out researches on the amount of solar heat and of atmospheric absorption and allied questions. One of them is kept as a standard at the Weather Bureau and may be used in Washington; the others are now located, respectively, in Baltimore, in care of Prof. J. S. Ames, and the other in Providence, R. I., in care of Prof. Carl Barus. Numerous investigations must be carried on by these physicists as preliminary to the main object of our research. Articles published in the MONTHLY WEATHER REVIEW by Prof. C. F. Marvin, Prof. F. W. Very, Mr. C. G. Abbott, and Prof. S. P. Langley have given a general idea of the scope that the investigation must take.

#### BAROMETRY.

The work on the barometry of the United States and Canada has been completed by Prof. Frank H. Bigelow, and the tables

for the reduction to sea level have been in operation since January 1, 1902, with results which seem to be quite satisfactory. The work of preparing and checking the station tables for reductions to the 3500-foot and the 10,000-foot planes is complete, and the individual tables will be issued during July, to be expanded at the stations, so that they will be ready for use in the autumn, as soon as the atmospheric circulation begins to be vigorous.

#### NEPHOSCOPIC OBSERVATIONS.

A very valuable set of nephoscope observations in the West Indian Islands has been secured, beginning May, 1889, and extending to May, 1902, at 11 stations. The circulation of the atmosphere in the tropical zone has never been carefully mapped out, and these observations for the first time afford us the necessary data for discussing these problems. In view of the popular interest in the distribution of the ashes ejected from Mont Pelée and La Soufrière in May and June, it is very opportune that the prevailing currents of air in the upper strata should be accurately determined. The computations on this work have been begun. Similarly, nephoscope observations will soon be commenced in the Pacific and Plateau districts, in order to supplement those made in 1896-97 for the international commission.

#### VAPOR TENSION AND PRECIPITATION.

It has become necessary to discuss the Weather Bureau observations on vapor tension throughout the United States, in view of the fact that no attempt has ever been made to construct any normals, or to determine the seasonal variation of the precipitation as depending upon this element. These computations will necessarily involve a careful treatment of the wet and dry bulb temperatures and a consideration of the troublesome psychrometric problems that are involved.

#### LOSS OF LIFE BY LIGHTNING IN THE UNITED STATES.

In Bulletin No. 30 the information collected from all parts of the country during the past ten years has been brought together and summarized by Prof. A. J. Henry. It is shown in this publication that destructive lightning strokes occur with greater frequency in some parts of the country than in others; that the region of greatest frequency is in the Ohio Valley, the lower Lake region, and the Middle Atlantic States, and that, considering the sparsity of the population, the number of fatalities in the middle Rocky Mountain region and the upper Missouri Valley is surprisingly large. A study of the data has also enabled the Bureau to formulate a few simple precautions against danger from lightning stroke that are here reiterated:

It is not judicious to stand under or near trees during thunderstorms, in the doorways of barns, near chimneys and fireplaces, or timbers that lead directly to the room. Neither should one stand near the point of entrance of telegraph and telephone wires. (The latter should invariably be provided with lightning arresters and ground wires.) It is not advisable to huddle under wagons, thrashing machines, or under frame structures surmounted by a flag pole. A wire clothesline should not be attached to a dwelling house under any circumstances; rather suspend it between two neighboring trees or posts.

#### WIND VELOCITY AND FLUCTUATIONS OF WATER LEVEL ON LAKE ERIE.

Strong westerly winds on Lake Erie pile up the water in the harbor of Buffalo, at the eastern end of the lake, the rise in level at times being so great as to be detrimental to navigation and injurious to wharf property. The establishment under the direction of the Chief of Engineers, U. S. Army, of self-recording water-level gages in Buffalo Harbor and at the western end of the lake, and the hearty cooperation of that official with the Bureau, has made it possible for Professor

Henry to study the relations between the force and direction of the wind and sudden changes in the level of lake waters.

It was found that with westerly winds of velocities less than 50 miles per hour at the eastern end of the lake the changes of level in Buffalo Harbor were not great enough to menace navigation; when, however, the velocity of westerly winds passes beyond 50 miles per hour, wharf property is always more or less exposed to danger from flooding. The height to which the water will rise depends partly upon the strength, duration, and suddenness of the westerly winds and partly upon the season of the year. The winds of the warm season seldom prevail long enough to cause an overflow. It was also found that while the crest of the rise in lake level and the maximum velocity of the wind generally coincided in point of time, the water would begin to fall as soon as the crest was reached, regardless of the force of the wind, and that it would continue to fall and then rise again, in a series of oscillations up and down, until the normal level was restored.

The relations between the velocity of the wind and dangerous changes in water level seem to be sufficiently definite to attempt to forecast them for the benefit of local interests at Buffalo and the western end of the lake, especially the last named, where a knowledge of the changes in depth of water in the channel at the mouth of the Detroit River would be of great value to navigation.

#### CONVENTION OF WEATHER BUREAU OFFICIALS.

The triennial convention of Weather Bureau officials met at Milwaukee, Wis., August 27-29, 1901. There were in attendance one hundred of the directing officials of the Bureau, representing every section of the country and every branch of the weather service. The entire scientific staff, consisting of seven professors, was present and took part in the proceedings. The Secretary of Agriculture honored the convention with his presence just before its close, and in a few well-chosen remarks congratulated the convention on the achievements of the weather service and the high standard of its personnel. The citizens of Milwaukee gave the members of the convention and their guests a banquet at the Pfister Hotel on the evening of the last day of the convention. The banquet was presided over by Hon. E. C. Wall, president of the chamber of commerce. The Press Club of Milwaukee also generously entertained the convention at a reception one evening during its stay in the city.

Much work valuable to the Government service was accomplished by this gathering together of the leading officials of the Bureau. The report of the convention has been printed as Bulletin No. 31. It comprises 250 pages and contains all of the papers read before and discussed by the convention. This report will be read and studied by the officials of the Bureau who were not in attendance at the convention. By thus printing and disseminating a complete report of the convention the younger observers and officials of the Bureau are given nearly as much benefit as though they had been in attendance. The printed report contains so many valuable papers and discussions that it will be found of great interest to many who are interested in meteorological problems and who are not connected with the Government. The esprit de corps and the devotion to their chosen profession of the officials of the Weather Bureau are well shown by the fact that, although it was required that they bear the expense of attendance upon the convention, except for transportation, practically all of the prominent officials of the Bureau were in attendance, and many others were anxious to go who could not be spared from their official duties.

#### WIRELESS TELEGRAPHY.

Experiments in space, or wireless, telegraphy were begun January 1, 1900, in accordance with the orders of the Secretary of Agriculture, and carried on under the direction of the Chief of the Weather Bureau. Prof. R. A. Fessenden was placed in immediate charge of the work and continued in that

capacity until July 30, 1902, when he was succeeded by Mr. A. H. Thiessen.

While much valuable information has been secured and a fairly satisfactory experimental system has been devised, I am not able to report such progress in the investigation as would justify the Department in dispensing with its coast telegraph lines or the cables that connect certain islands with the mainland.

The hot-wire receiver, or boloscope, was found to be the most sensitive of any yet used in the experiments. Its action was positive, and during the early spring it gave excellent results; messages were transmitted with a rapidity almost equal to that of the ordinary telegraph. Quite satisfactory tests were made before a board from the Army and one from the Navy. It was thought that the Bureau had finally devised a receiver that would take the place of all others in use; but as the season advanced into summer and unstable atmospheric electrical conditions became more frequent it was found that the minute platinum loops on which the active principle of the boloscope depended would frequently burn out after connection was made with a vertical wire.

It has so far been found impossible to send messages any appreciable distance over land or fresh water or to attune the transmitter to the receiver so as to overcome the difficulties of interference should a second transmitter generate electric waves within the same field.

I am of the opinion that the use of wireless telegraphy in its present state is limited to the transmission of messages between moving ships and between ships and the land, and that wherever permanent communication is required the cable or the land wire is the more reliable means of communication and probably the more economical.

Our experiments during the past year were conducted over a course between Manteo and Cape Hatteras, N. C., a distance of about 50 miles.

#### INSTRUMENTS.

##### STATION EQUIPMENTS.

Nearly all stations are now fully equipped with automatic instruments recording wind velocity and direction, the temperature and pressure of the air, and the duration of sunshine and rainfall. The extensive and thorough inspection of stations that has been made within the last two years has resulted in numerous recommendations by the inspectors, which, in the main, have been carried out and which have necessitated the replacing of old automatic apparatus with that of the most approved type. We have been obliged to postpone the equipment of some stations already listed to be supplied, but it is expected that these will receive attention during the next few months.

It is considered, in the present connection, that a station is fully equipped with automatic instruments whenever records of the following meteorological conditions are continuously and automatically produced, namely: Wind velocity, wind direction, temperature, pressure, rainfall, duration of sunshine.

On June 30, 1902, there were in operation 191 stations at which at least one meteorological element was automatically recorded, and in order to set forth graphically the present status of the equipment of stations, these may be separated into the following classes:

(a) Stations completely equipped as defined above .....	124
(b) Stations awaiting equipment as supplies become available .....	24
(c) Stations maintained by agents where the equipment is necessarily simple and hence incomplete .....	9
(d) Special display or other stations, at which records of some particular element, generally wind velocity only, is desired .....	17
(e) Regular stations now partly equipped, but which are of small importance, or so circumstanced that further additions to the present equipment are not considered desirable or necessary ..	17
Total .....	191
(f) New stations announced but not yet established.	

In connection with the 124 stations quoted as completely equipped, it should be remarked that in addition to the automatic registers and apparatus constituting a complete equipment, 105 of the 124 stations are provided with a special so-called instrument stand, on which the automatic registers are installed to advantage, including an extra anemometer, a whirling apparatus, maximum and minimum thermometers, and a glass sunshine recorder, all arranged to exhibit these devices to visitors, etc. In order to still further improve the equipment and furnishings of stations, a series of 26 climatic and meteorologic charts were prepared and printed and sets issued to stations about two years ago. Some of these were bound, some framed separately and hung up on the walls of the offices, but finally during the past year a special set of swinging frames of ornamental pattern was designed, and about 79 stations have thus far been supplied with them. Stations with ample wall space have displayed the charts in separate frames. There are about 20 stations of this number at which 15 or more of the charts are so displayed (in wall frames). We thus have 124 stations completely equipped with automatic instruments, and the greater part of them provided in addition with special instrument stands, framed climatic charts, and extra instruments arranged for exhibit. It must be noticed that of those not equipped with instrument stands, charts, etc., many, such as the West Indian stations, for example, and some in the United States, do not really require or can not use this part of the standard outfit.

Referring again to the classified list above, it appears that if we exclude classes (c), (d), and (e), the stations of which do not require further equipment, and class (f), which pertains to the future, there remain 124 stations of the Bureau now fully equipped and 24 stations in process of equipment.

On the whole, it may be stated that the latter are now about one-half equipped; that is to say, about twelve complete sets of apparatus will be required to complete the equipment. It is confidently expected that the entire equipment at all stations will thus be completed during the current fiscal year.

#### STORM-WARNING EQUIPMENT.

The work of extending the equipment of steel towers and high-power lanterns of improved type at important storm-warning stations has also constituted an important piece of work assigned to the Instrument Division, which is directed by Professor Marvin, and this was pushed energetically during the year, as far as funds would permit. In all, 54 towers have been distributed to storm-warning stations, of which number 4 were to regular stations for special purposes. Of those issued, only 3 have not yet been erected, owing to unavoidable delays in procuring satisfactory sites and the exorbitant nature of bids for erection.

The funds available for this work during the past year were too limited to permit of the purchase of the high-power lanterns and certain other accessories required with the towers, hence none were provided. Moreover, the first six months of the past year have been mostly consumed, of necessity in the manufacture, shipment, and installation of the towers, hence the plan was adopted of spending the sum available mostly for towers and their installation, leaving the matter of lanterns and accessories to be supplied this year. Provision for this has already been made, but the storm-warning fund will permit of no considerable extension of the work beyond finishing matters left over from last year.

There are now 109 storm-warning and 9 special stations at which the steel towers have been installed. Of these, 48 now need lanterns, which will be issued as soon as delivered by the contractor.

#### TESTING AND ADJUSTING INSTRUMENTS.

This important work has grown to very great proportions with the large extensions of the service during the past few years.

All automatic instruments and registers, not only new instruments, but old ones that have been repaired, are most carefully tested in actual work and adjusted before the instruments are put in operation at stations. But few of the observers have that intimate knowledge of the theory of all these apparatus or the skill that is required to set in order instruments that may be generally out of adjustment. This delicate and important work is performed, under the direction of Professor Marvin, in a most conscientious and intelligent manner by Mr. Charles B. Tuch, whose skill and long experience with meteorological apparatus renders his service of the greatest value.

The comparison of thermometers likewise involves a large amount of painstaking, technical work. During the year about 1400 thermometers were inspected and compared. The temperatures at which comparisons are made range from 40° below zero to 112° above, and thermometers are compared at points every 10° along the scale, with the exception of maximum thermometers, which are not compared at points below 32°. This means at least nine readings on every thermometer and four to six additional readings at low temperatures on all mercurial and alcohol thermometers, making an average of about thirteen readings for each thermometer. This work and that of deducing and tabulating the corrections from the thousands of readings involved is performed in the most satisfactory manner by Mr. Samuel A. Potter.

It is only by such a rigid system of inspection, testing, comparison, and adjustment of instrumental apparatus that a high standard of reliability can be maintained, and it may fairly be affirmed that the instruments of the United States Weather Bureau are unsurpassed in respect to their uniform excellence and accuracy by similar instruments anywhere.

#### MACHINE SHOP.

During the past year the old, antiquated foot lathes, formerly constituting the entire equipment of our repair shop, were replaced by new power-driven lathes and some other machinery.

The repair work on instruments fell considerably in arrears during the period of transition from the old to the new machinery, not only because of the time required in the installation and refitting of the shop, but from the fact that the complete utility of the new machinery depends upon securing a multitude of special tools, cutters, dies, jigs, etc., suited to the particular work in hand; and a great deal of time was expended in the construction of such special tools. Therefore the full value of our improved equipment will only be realized as these special accessories multiply and become more varied with continued work.

For many years we have had but two skilled mechanics in the machine shop, and in the meantime the number of complex automatic instruments at stations has increased from 10 or 15 pieces for the entire service to about 800 now in actual use throughout the service. Some of these are exposed to all degrees of weather conditions, and all are subject to more or less deterioration and wear with use. An increase in the force of skilled mechanics is much needed, in order to properly keep up the repair work on the great number of instruments now in use.

#### INSTRUMENTAL RESEARCH WORK.

The routine operations of the Instrument Division have so wholly absorbed the time, thought, and energies of Prof. C. F. Marvin, the able chief of the division, and the persons engaged therein as to leave them little opportunity for serious application to the many unsolved technical problems involved in the construction and operation of meteorological apparatus. In former years the volume of routine work was much smaller and less exacting than at present; but we earnestly look forward to a time in the near future when the burden of routine duties shall diminish because of the completed state of the

instrumental and storm-warning equipments. Then our experts will be able to devote at least a portion of their time to special problems.

Professor Marvin expresses high appreciation of the conscientious application and ability with which Mr. D. T. Maring, the assistant chief of the instrument division, has assisted him.

## OBSERVATORY BUILDINGS.

In the act making appropriations for the Department of Agriculture for the fiscal year ended June 30, 1902, approved March 2, 1901, Congress included an item for the purchase of a site and erection of a small brick and wooden building at each of the following-named stations for the use of the Weather Bureau, at the amounts set opposite each, viz: Atlantic City, N. J., \$6000; Hatteras, N. C., \$5000; Fort Canby, Wash., \$4000; Port Crescent, Wash., \$3000; Tatoosh Island, Wash., \$5000, and Point Reyes, Cal., \$3000; and for the purchase and laying of a cable between the mainland and Tatoosh Island, Wash., including general repairs to telegraph line from Port Crescent to Tatoosh Island, Wash., \$20,000; in all, \$46,000, with the proviso that if any of the money for these several buildings and cable remained unexpended it might be used in the repair, improvement, and equipment of the buildings owned by the Government and occupied by the Weather Bureau at Cape Henry, Va., Bismarck, N. Dak., Kittyhawk, N. C., and Jupiter, Fla.

Under this authority the work was immediately taken up by the Weather Bureau, and the following buildings were erected during the year at the total cost set opposite each, viz:

Atlantic City, N. J.	\$6,000.00
Hatteras, N. C.	5,000.00
Fort Canby (North Head), Wash.	3,992.63
Port Crescent, Wash.	1,000.00
Tatoosh Island, Wash.	4,950.00
Point Reyes, Cal.	2,989.90
Total	23,932.53

In addition, the following buildings were also repaired, improved, and equipped, and supplies purchased therefor at the total cost set opposite each, viz:

Bismarck, N. Dak.	\$7,064.14
Jupiter, Fla.	3,358.00
Kittyhawk, N. C.	125.00
Cape Henry, Va.	5,104.25
Supplies, instruments, etc.	1,647.64
Total	17,279.03

In regard to the above, however, it may be proper to add that the buildings at Port Crescent, Wash., and Jupiter, Fla., are still in course of construction, but it is expected that they will be completed within the next three months.

It was deemed advisable not to lay a cable between Tatoosh Island and the mainland, Wash., but instead to build a span wire across, in order that the balance of the money thus created might be used in the repair and improvement of the buildings above mentioned. General repairs, however, are now being made to the telegraph line from Port Crescent to Tatoosh Island, Wash., at an approximate cost of \$3000, which leaves a balance of about \$1768.44 to be covered into the Treasury. Only such portion of this special appropriation has been expended as has been absolutely necessary for the work in question, and while the unexpended balance can be used for the purchase of supplies for any of the buildings named, I have felt it my duty not to incur any additional expense against this fund, as I believed that the buildings in question were sufficiently well equipped to meet the needs of the Weather Bureau.

The press has spoken in high terms of the benefit that the buildings will be to the marine and other interests.

In view of the complimentary criticisms from the public and the economy to the Government in owning its own buildings,

thereby saving the amounts now paid for rent of office quarters, I recommended that an additional appropriation of \$50,000 be asked from Congress for the purchase of sites and the erection of not less than six buildings during the fiscal year ending June 30, 1903, which you approved, and Congress has made an appropriation of the amount named. The places that have been selected for these new buildings, with your approval, are Yellowstone Park, Wyo.; Amarillo, Tex.; Modena, Utah; Key West and Sand Key, Fla., and South Farallone Island, Cal. There has been some difficulty in providing sites for the buildings at Modena and Amarillo, and it is not believed that it will be practicable to erect these buildings before next spring.

## LIBRARY.

No change has been made in the ordinary routine of the library. The facility with which the library can be consulted has been greatly enhanced by the completion of the transcribing of the author index on cards of better size (standard library). Work has been begun on a subject index, a most important adjunct to a library, and one the need of which has been acutely felt for years past. No unforeseen interruption occurring, this much needed index should be completed within the current fiscal year. Conjointly with this subject index of books, author and subject indexes of the meteorological contents of the periodicals currently received have also been started. Bibliography is imperative in scientific research, and as soon as the present exigencies admit, more attention will be devoted to the subject of meteorological bibliography. An endeavor will be made to close the hiatus between the suspension of our bibliographic work some ten years ago and its partial resumption within the last year.

The number of volumes in the library has been increased during the year by 782 accessions, most of which are meteorological reports of other weather services. Many of these works can not be accommodated for lack of space, but remain in sacks and packages stored on the floor. Arrangements, therefore, will soon be made to assign additional room to the library. The Bureau now especially encourages the study of meteorology, not only in the public schools but also in the colleges and the universities of the country. This action is attracting the attention of teachers and students to the Central Office. It is a place for study; a place where the advantages of the collected data of the world may be obtained, and it is the only place of the sort in this country. In modern research work two instrumentalities stand out coequal and coimportant—library and laboratory—the library, from which to learn what other workers have thought and done; the laboratory, in which to test that which is newly thought out. The use made by our own officials of the library may be best shown by the fact that there are at present more than 550 volumes charged to and in use in the different divisions and sections of the office. No record has been kept of daily calls for books, but it is not improbable that more than a thousand books are taken out of the library for consultation annually. Having what we believe to be the largest and most complete meteorological library extant, it will be our aim to make it the most useful.

## EXAMINATIONS.

There have been held during the year 71 examinations—36 of employees not previously examined in any branch, and 35 of employees who had passed the first-grade examinations and were taking the examinations prescribed for one or more of the other grades. It is believed that the purposes of the examinations would be greatly furthered if the questions as marked, together with the reasons for the marking, could be submitted to the examinee, and the supervising examiner has been instructed to do so in the future. To tell one that he is in error is necessary, but to tell one how he comes to be in error is more important—it is educative.

## TELEGRAPH LINES.

No change has taken place since the last annual report in the total mileage (367 miles) of telegraph and telephone lines owned and operated by the Weather Bureau, no new lines having been built nor any old ones abandoned during the year.

No extensive line repairs have been needed except on the Tatoosh Island section, where general repairs are now underway, preparatory to the reestablishment of telegraphic communication with the new station about to be erected on that island. A wire span, supported on steel towers, is in course of erection between the island and the mainland, in lieu of a submarine cable which, as costly experience during past years has demonstrated, can not be economically maintained in that locality.

Nineteen nautical miles of two-conductor cable, laid by the Signal Service of the Army in 1898, between Block Island and Narragansett, R. I., were recently transferred to this Bureau. This cable has been out of working order since January. It was our purpose to recover it, replace the defective parts, and relay it so as to parallel our old Block Island cable for use in case of an accident to the latter. On taking it up it was found to be too badly worn to justify the expense of again putting it down, and an appropriation of \$40,000 is recommended for the purchase and the laying of a new cable and the purchase of ground and erection of necessary buildings at each of the two termini.

The total "this line" receipts from commercial telegrams transmitted over Weather Bureau lines during the year were \$2326.17, an increase of \$597.68 over last year's receipts.

The total number of whole days and fractional parts of a day, respectively, on which telegraphic communication over Weather Bureau lines was interrupted is as follows:

From—	Whole days.	Fractional days.
Port Crescent to Neah Bay, Wash.	10	55
San Francisco to Point Reyes, Cal.	26	15
Edgartown to Nantucket, Mass.	0	0
Block Island to Narragansett, R. I.	2	4
Norfolk, Va., to Hatteras, N. C.	5	47
Alpena to Middle Island, Mich.	1	6
Alpena to Thunder Bay Island, Mich.	0	0

Under acts passed by the last Congress, specifications and plans are being prepared for purchasing and laying about 50 statute miles (more or less) of submarine telegraph cables, to connect Sand Key, Fla., with Key West, Fla.; South Manitou Island, Mich., with Glenhaven, Mich., and the Farallone Islands, Cal., with San Francisco, Cal., via Point Reyes, Cal. A teredo-proof, one-conductor cable, with rubber insulation and twelve No. 8 guard wires, will be used for the Sand Key connection, and gutta-percha cables, with twelve No. 5 guard wires, for the others.

A short telephone line, to connect the new station at North Head, Wash., with the lines terminating at Fort Canby, Wash., is now under construction.

## PUBLICATIONS.

The publications during the fiscal year may be summarized as follows:

	TOTAL OUTPUT.	Pieces.
Forecast cards:		
Manila	15,785,760	
Paper	2,370,105	
Station maps	4,087,792	
Station forms, all kinds	2,738,130	
Weather maps, Washington	539,772	
Climate and crop bulletins	140,089	
Monthly Weather Reviews	52,750	
Lake charts	44,500	
Snow and ice bulletins	31,043	
Total	25,789,941	

These figures relate only to work done within the Publications Division, and do not include miscellaneous printing for the Bureau done outside under authority of over 800 orders. They mean that 25,790,000 pieces, weighing more than 270 tons, were here printed, cut, bound or otherwise made into suitable packages, wrapped, and mailed.

## WORK DONE AT THE GOVERNMENT PRINTING OFFICE.

	Pieces.
Forecast cards:	
Manila	13,000,000
Paper	13,000,000
Station maps	3,450,000
Total	29,450,000

These were also mailed to stations.

Other printing done at the Government Printing Office includes 2 quarto bulletins, aggregating 2700 copies; 7 octavo bulletins, aggregating 24,500 copies, and 625,000 miscellaneous forms.

To the above quantities are to be added 2,250,000 blank forecast cards, manila, shipped direct by the contractor to stations, and 2,000,000 paper forecast cards printed here previous to, but mailed after June 30, 1902.

## ECLIPSE METEOROLOGY AND ALLIED PROBLEMS.

The track of the total solar eclipse of May 28, 1900, crossed the Southern States from New Orleans to Norfolk and afforded an unusual opportunity for studying some of the physical problems connected with the effects of solar radiation in the earth's atmosphere. The observations made in the eclipse track have been discussed by Prof. Frank H. Bigelow, and the results appear in Bulletin I, Weather Bureau, 1902, Eclipse Meteorology and Allied Problems. It is there shown what preliminary meteorological observations should be made for determining the position of eclipse stations. Professor Bigelow demonstrates that the so-called eclipse cyclone does not exist in the atmosphere; he also shows that the shadow bands are due to the light from the sun's crescent shining through the interstices of the mixture of currents of different densities that exist in the lowest layers of the atmosphere. A review of the scientific status of the problems of solar physics follows, in which the parallelism between the meteorology of the sun and that of the earth is indicated.

## GENERAL CLIMATIC CONDITIONS.

By W. B. STOCKMAN, Forecast Official, in charge of Division of Meteorological Records.

## ATMOSPHERIC PRESSURE.

The numerical values of annual mean pressures for 1902 are given in Tables I and VI. The departures are given in Table I.

The method of reduction of the observed pressures to sea level, standard gravity, and to the mean of 24 hourly observations is that adopted by the Bureau on January 1, 1902, and fully described on pages 13-16 of the MONTHLY WEATHER REVIEW for that month.

The sea-level values thus obtained are shown on Chart I.

The pressure on the 10,000-foot plane is also obtained as indicated on the same pages of the above-mentioned REVIEW, and the resulting isobars are shown on Chart II.

The mean annual barometric pressure was highest over Kentucky, Tennessee, the northern portion of the east Gulf States, and parts of the South Atlantic States, and lowest over the southern Plateau region. Except in parts of the central portions of Kentucky and Tennessee, and on the coast of cen-

tral California, the annual pressure values were below the normal. In the regions where the pressure was above the normal the departures were not so large as they were where negative. The location of the areas of highest and lowest mean annual pressure did not materially differ from that for the year 1901.

#### TEMPERATURE.

The distribution of mean surface temperature is shown on Chart III and the district departures by Table VIII.

The mean annual temperature was below the normal in southeastern Washington, Nevada, eastern and southern California, western Arizona, West Virginia, southern Ohio, Kentucky, Indiana, central Illinois, central Missouri, the Florida Peninsula, and parts of the South Atlantic States, but, as a rule, with slight departures. Elsewhere it was above normal, and generally with departures greater than where they were below. The areas of plus and minus departures as determined by a consideration of reports from Climate and Crop centers differ slightly in location from those based on reports from regular Weather Bureau stations only, but the difference in position is not marked. In Arkansas the departures during the fall months averaged nearly  $5^{\circ}$  per day above the normal. In Georgia July was the warmest in eleven years; in Mississippi June, August, and November were the warmest of record, as also was November in Kentucky and West Virginia. June was the coolest of record in West Virginia.

#### PRECIPITATION.

The distribution of annual precipitation is shown on Chart IV and the district departures by Table IX.

The precipitation was deficient generally in the Atlantic and Gulf States, eastern lower Lake region, northwestern upper Lake region, upper Missouri Valley, the Plateau regions, and portions of California. In eastern Massachusetts the deficiency amounted to about 11 inches; in southeastern Virginia, the eastern portions of the Carolinas, east-central Florida, and the Gulf coast, except at Corpus Christi, from 13 to 26.3 inches; at Escanaba, Mich., 10.2 inches, and Erie, Pa.,

11.5 inches. Tacoma, Wash., reports an excess of 10 inches; Seattle, Wash., 9.9 inches; Eureka, Cal., 12.5 inches, and Lincoln, Nebr., 14.4 inches; elsewhere the excess departures were, as a rule, not very large. Over southeastern New York, Delaware, New Jersey, southeastern Pennsylvania, eastern Maryland, the District of Columbia, and northern Virginia the precipitation was in excess from 2.3 to 9.9 inches, and in the area surrounding this locality the departures were markedly deficient. Similar conditions obtained between northeastern and east-central Florida, about Lake Erie, northwestern and west-central California, and portions of the Missouri Valley and northern slope. Kansas and Oklahoma report the heaviest annual precipitation of record.

The amount of snow on the ground at the end of the year was deficient over the eastern slope of the Big Horn Mountains, in Wyoming. In all other mountain districts the amount of snow on the ground indicates a good flow of water for irrigation purposes during the coming crop season.

#### THUNDERSTORMS.

The frequency of thunderstorm days in the different months and in the several States and Territories is shown approximately by the figures of Tables III and IV.

The first-named table has been prepared from reports of both regular and voluntary observers, with a view to showing the number of thunderstorm days recorded each month in the immediate neighborhood of the respective stations.

The second table shows the number of days on which thunderstorms were recorded in the State or Territory as a whole. In preparing the last-named table reports from all stations whatsoever were used. The number of thunderstorm days for a given State, as shown in Table IV, depends largely upon the size of the State and the number and distribution of the observing stations. In the District of Columbia, for example, with but one observing station, the number of thunderstorm days was 48, while for the adjacent State of Maryland, with an average of 48 stations, thunderstorms were observed on 113 days. In Virginia, with about 52 stations, the number of thunderstorm days was 127.

TABLE I.—Annual climatological summary, Weather Bureau stations, 1902.

Districts and stations.	Elevation of barometer above sea level.	Pressure in inches.†			Temperature of the air, in degrees, Fahrenheit.						Precipitation.		Winds.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall, inches. †.				
		Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.—mean min. +2.	Departure from normal.	Maximum.	Mean maximum.	Minimum.	Mean minimum.	Annual range.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Total, in inches.	Departure from normal.	Days with .01, or more.						Total movement, miles.	Prevailing direction.	Max. velocity.	
																								Miles, per hour.	Direction.
<i>New England.</i>																									
Eastport	76	29.86	29.94	-.03	47.0	+0.4	84	50	-15	36	99	36	79	41.47	-2.18	167	96,337	sw.	54	e.	97	113	185	6.2	83.5
Portland, Me.	103	29.83	29.95	-.03	45.4	+0.3	90	53	-14	38	104	36	74	47.75	+3.49	133	82,003	nw.	44	s.	127	96	142	5.6	61.
Northfield	876	29.02	29.99	-.02	41.2	+0.0	88	52	-19	31	107	35	80	38.33	+3.73	169	73,117	s.	40	nw.	52	119	194	7.0	86.
Boston	125	29.84	29.98	-.03	49.6	+1.0	92	57	-8	42	100	41	74	33.93	-11.03	117	98,517	w.	46	w.	128	90	147	5.6	45.
Nantucket	12	29.97	29.98	-.04	49.2	+0.4	80	54	-1	44	81	43	82	35.97	-4.76	135	129,649	sw.	64	e.	79	154	132	6.2	54.
Block Island	26	29.96	29.99	-.03	49.3	+0.2	80	55	-1	44	81	43	80	45.63	+1.44	136	.....	sw.	73	ne.	125	141	99	4.9	28.4
Narragansett	.....	.....	.....	.....	48.7	+0.1	88	57	-5	40	93	40	74	44.42	+4.94	122	.....	sw.	.....	.....	188	61	116	.....	43.3
New Haven	106	29.87	29.99	-.04	49.8	+0.4	90	58	-5	42	95	40	74	44.33	+3.58	139	82,339	n.	57	ne.	171	85	109	4.6	36.1
<i>Middle Atlantic States.</i>																									
Albany	97	29.89	30.00	-.03	48.0	+0.2	92	57	-11	39	103	39	76	37.48	-0.38	154	67,161	s.	47	w.	99	109	157	6.2	55.6
Binghamton	875	29.05	29.99	-.05	46.6	+0.2	89	56	-9	38	98	38	70	36.70	-0.58	171	57,303	w.	36	sw.	58	147	160	6.6	61.0
New York	314	29.66	30.00	-.04	52.6	+0.9	91	59	-8	46	83	42	72	47.07	+2.27	140	128,906	nw.	74	nw.	113	112	140	5.7	31.3
Harrisburg	374	29.62	30.03	-.02	51.9	+0.4	95	60	-7	44	88	42	72	39.84	+4.22	123	66,530	w.	49	w.	97	128	140	5.9	35.5
Philadelphia	117	29.89	30.02	-.03	54.2	+0.8	95	62	-12	46	83	43	71	49.76	+9.92	128	96,244	nw.	52	n.	130	103	132	5.4	28.8
Seranton	805	29.14	30.01	-.03	48.8	+0.2	90	58	-2	40	88	39	71	45.05	.....	146	66,283	sw.	48	nw.	74	127	164	6.6	58.1
Atlantic City	52	29.96	30.02	-.02	52.4	+0.5	94	59	-12	46	82	46	82	50.38	+7.87	132	81,170	nw.	43	e.	126	166	73	4.9	33.7
Cape May	17	29.02	30.04	-.00	53.0	+0.6	92	59	-14	47	78	47	78	47.90	+4.02	130	77,124	nw.	43	s.	123	161	81	5.0	18.5
Baltimore	123	29.88	30.01	-.04	53.2	+0.0	99	63	-13	47	86	45	73	50.13	+6.18	122	60,166	w.	70	w.	107	126	132	5.6	33.4
Washington	112	29.90	30.02	-.04	54.9	+0.2	99	64	-5	46	94	44	72	46.58	+3.12	121	62,125	nw.	40	nw.	114	132	89	4.8	13.1
Lynchburg	681	29.28	30.02	-.05	56.8	+0.1	99	67	-13	47	86	45	71	48.79	+5.94	99	40,337	nw.	40	nw.	135	139	91	4.9	10.3
Norfolk	91	29.93	30.03	-.02	59.3	+0.3	98	67	-18	51	80	50	78	38.48	-13.60	117	83,142	s.	54	nw.	175	109	81	4.4	11.5
Richmond	144	29.88	30.03	-.03	58.1	+0.1	98	68	-15	49	83	.....	.....	49.32	.....	107	49,036	n.	40	s.	129	106	130	5.3	15.8
<i>South Atlantic States.</i>																									
Charlotte	773	29.21	30.05	-.02	60.2	+0.3	98	69	-16	51	82	49	72	43.32	-6.60	124	56,985	ne.	42	w.	147	112	106	4.9	17.7
Hatteras	11	30.02	30.03	-.03	61.6	+0.2	92	67	-24	56	68	55	84	40.13	-26.28	109	120,436	sw.	60	sw.	161	101	103	4.7	7.7
Raleigh	376	29.64	30.04	-.02	59.9	+0.8	100	70	-17	50	84	48	72	39.16	-6.93	123	54,914	sw.	32	sw.	152	99	114	5.0	18.8
Wilmington	78	29.95	30.03	-.03	62.7	+0.3	101	71	-19	54	81	53	76	34.58	-19.76	113	73,896	sw.	45	w.	137	149	79	4.6	0.5
Charleston	48	30.00	30.05	-.02	65.7	+0.1	103	73	-23	59	80	57	78	37.22	-19.52	108	94,048	sw.	45	sw.	108	193	64	4.8	0.1
Columbia	351	29.67	30.05	-.02	63.1	+0.6	101	73	-18	54	83	51	72	46.20	-1.35	126	69,777	ne.	53	sw.	123	141	101	5.2	5.9
Augusta	180	29.85	30.04	-.03	64.1	+0.2	102	74	-19	54	83	74	41.79	-6.53	105	53,184	nw.	45	ne.	177	104	84	4.3	1.1	
Savannah	65	29.98	30.05	-.01	67.0	+0.6	101	75	-24	59	77	58	80	47.35	-4.56	111	69,319	sw.	42	w.	158	152	55	4.2	0.0
Jacksonville	43	29.98	30.03	-.03	68.9	+0.1	101	77	-24	60	77	59	77	55.52	+1.49	127	74,157	se.	55	s.	135	144	86	4.6	7.1
<i>Florida Peninsula.</i>																									
Jupiter	28	29.99	30.02	-.01	74.4	+0.8	96	81	-38	68	58	66	79	45.79	-13.89	119	91,963	se.	48	sw.	125	202	38	4.6	0.0
Key West	22	29.98	30.00	-.02	76.4	+0.7	91	80	-80	72	41	67	76	38.61	+0.15	89	80,785	e.	36	ne.	167	150	48	4.2	0.0
Tampa	34	29.99	30.03	-.01	71.5	+0.1	96	80	-29	63	67	62	79	50.38	-4.33	103	56,552	ne.	49	s.	111	166	88	5.1	0.0
<i>East Gulf States.</i>																									
Atlanta	1,174	28.81	30.05	-.02	61.1	+0.1	98	70	-15	52	83	48	70	43.96	-6.42	111	107,124	nw.	51	n.	116	136	113	5.3	0.6
Macon	370	29.65	30.05	-.01	63.8	+0.4	101	74	-17	54	84	.....	.....	38.00	.....	109	55,512	nw.	55	s.	124	94	147	5.5	3.3
Pensacola	56	29.98	30.04	-.01	68.0	+0.4	97	75	-24	61	73	.....	.....	41.54	-13.55	102	87,323	ne.	52	sw.	141	133	91	4.8	0.0
Mobile	57	29.98	30.04	-.01	67.2	+0.5	98	75	-23	59	73	58	77	48.66	-13.95	114	64,367	n.	46	sw.	166	91	108	4.7	0.0
Montgomery	223	29.80	30.03	-.03	65.6	+0.4	101	75	-17	56	84	53	71	48.62	-4.10	100	59,506	e.	46	e.	142	106	117	5.0	T.
Meridian	375	29.64	30.04	-.02	63.9	+0.1	102	74	-16	54	86	.....	.....	50.06	-4.60	105	48,339	sw.	38	e.	130	133	102	0.0	0.3
Vicksburg	247	29.74	30.00	-.06	65.7	+0.4	99	74	-22	57	77	53	72	47.31	-8.35	96	59,805	se.	41	w.	134	116	115	5.1	0.2
New Orleans	51	29.97	30.02	-.02	69.4	+0.6	98	77	-28	62	70	59	77	41.61	-18.91	97	74,187	se.	42	ne.	110	142	113	5.5	T.
<i>West Gulf States.</i>																									
Shreveport	249	29.75	30.02	-.01	65.6	+0.4	100	75	-23	56	77	56	77	49.88	+1.28	99	59,956	se.	40	sw.	150	112	103	4.9	1.4
Fort Smith	457	29.51	29.99	-.04	61.1	+1.3	101	70	-10	52	91	48	70	35.12	-9.62	106	78,391	e.	64	w.	96	199	70	4.9	12.8
Little Rock	357	29.65	30.03	-.01	61.7	+0.2	97	70	-16	54	81	50	71	33.99	+0.36	103	63,449	s.	46	sw.	141	132	92	4.8	3.2
Corpus Christi	20	29.96	29.98	-.01	71.5	+1.4	95	77	-28	66	67	63	80	21.59	-8.61	71	101,446	se.	42	nw.	152	152	61	4.4	0.0
Fort Worth	670	29.28	29.98	-.03	65.6	.....	103	76	-13	56	90	.....	.....	29.31	.....	82	103,502	s.	32	s.	176	124	65	3.9	2.3
Galveston	54	29.92	29.98	-.05	69.7	+0.1	91	74	-32	66	59	62	81	37.67	-11.01	91	103,808	se.	32	ne.	159	124	82	4.6	0.0
Palestine	510	29.47	30.01	-.01	66.0	+0.8	97	75	-18	57	79	56	77	39.76	-6.75	97	67,556	s.	48	sw.	130	127	108	5.2	5.4
San Antonio	701	29.24	29.96	-.03	69.9	+1.4	103	80	-26	60	77	55	67	24.79	-4.91	79	69,832	se.	65	w.	123	142	100	5.1	T.
Taylor	863	29.38	29.99	-.01	67.6	.....	100	78	-18	57	82	.....	.....	33.13	.....	85	86,594	s.	40	e.	152	114	99	4.7	1.3
<i>Ohio Valley and Tenn.</i>																									

TABLE I.—Annual climatological summary, Weather Bureau stations, 1902—Continued.

Districts and stations.	Elevation of barometer above sea level.	Pressure in inches.†			Temperature of the air, in degrees Fahrenheit.					Precipitation.		Winds.			Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall, inches. ‡						
		Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ±2.	Departure from normal.	Maximum.	Mean maximum.	Minimum.	Mean minimum.	Annual range.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Total, in inches.						Departure from normal.	Days with .01 or more.	Total movement, miles.	Prevailing direction.	Max. velocity.	
																								Miles, per hour.	Direction.
<i>Upper Miss. Val.—Cont'd.</i>																									
St. Paul	837	29.07	29.99	-.02	45.0	+1.7	88	53	-18	37	106	35	74	31.75	+4.28	119	69,950	nw.	48	nw.	99	150	116	5.7	20.0
La Crosse	714	29.23	30.01	-.01	46.7	+0.7	91	56	-24	38	115	41	76	30.26	+0.42	116	67,059	s.	40	w.	98	152	115	5.5	26.3
Davenport	606	29.34	29.98	-.05	49.6	+0.4	92	58	-13	41	105	41	76	40.31	+6.59	119	67,654	w.	40	s.	134	106	125	5.3	11.1
Des Moines	861	29.09	30.02	-.00	49.2	+0.7	94	58	-16	40	110	40	76	42.01	+8.90	121	77,440	sw.	48	w.	82	165	118	5.8	29.8
Dubuque	698	29.25	30.00	-.02	48.1	+0.5	90	57	-18	40	108	38	73	38.34	+2.81	130	60,099	nw.	35	sw.	100	124	141	6.1	20.5
Keokuk	614	29.34	30.00	-.03	51.9	+0.5	96	60	-10	43	106	43	77	38.86	+4.14	115	68,175	sw.	48	sw.	143	114	108	4.8	10.1
Calro	356	29.66	30.04	-.01	58.1	+0.4	98	66	-7	50	91	49	76	33.07	+9.76	108	72,225	s.	52	sw.	89	163	113	5.6	12.4
Springfield, Ill.	644	29.33	30.00	-.04	52.2	+0.1	94	61	-8	44	102	43	75	36.71	+1.30	129	82,261	sw.	48	w.	113	116	136	5.6	21.0
Hannibal	534	29.44	30.02	-.01	52.6	+0.1	94	62	-8	45	102	43	75	35.02	+1.57	113	80,999	sw.	52	w.	116	135	114	5.4	13.5
St. Louis	567	29.41	30.01	-.03	57.5	+1.9	98	64	-1	49	99	46	72	38.43	+2.65	125	80,479	s.	54	n.	139	110	116	5.2	15.2
<i>Missouri Valley.</i>																									
Columbia	784	29.18	30.03	-.00	53.3	+1.7	94	63	-11	44	105	43	72	44.34	+4.41	117	72,382	s.	48	w.	117	109	139	5.6	25.5
Kansas City	963	28.99	30.03	-.01	54.1	+0.9	96	63	-7	46	103	43	72	40.52	+4.18	114	73,432	s.	55	nw.	143	97	125	5.1	24.1
Springfield, Mo.	1,324	28.61	30.01	-.02	54.9	+0.0	93	63	-3	47	96	47	79	49.30	+5.13	124	93,222	se.	42	w.	181	83	101	4.5	26.3
Topeka	1,189	28.70	29.97	-.04	53.4	+0.4	100	63	-10	44	110	40	73	41.22	+0.93	110	82,280	s.	44	sw.	100	153	112	5.3	24.3
Lincoln	1,105	28.80	29.99	-.03	50.4	+0.8	96	59	-12	42	108	40	72	30.48	+1.21	109	76,342	se.	32	nw.	107	138	120	5.6	18.5
Omaha	2,598	27.22	29.94	-.06	46.4	+0.1	106	59	-26	34	132	33	68	13.61	+5.54	99	94,834	nw.	49	nw.	159	128	78	4.4	30.6
Valentine	1,135	28.77	30.00	-.02	47.5	+0.5	95	57	-21	38	116	33	68	20.34	+4.62	113	112,305	nw.	74	n.	121	116	108	5.1	37.2
Sioux City	1,572	28.30	29.98	-.02	46.7	+1.3	108	57	-22	36	130	32	64	20.04	+4.27	98	70,698	se.	67	nw.	144	103	118	5.1	26.7
Pierre	1,306	28.58	30.00	-.01	49.8	+1.5	101	55	-26	32	127	34	74	16.42	+4.61	91	102,512	se.	58	s.	131	157	77	5.0	16.8
<i>Northern Slope.</i>																									
Havre	2,505	27.29	29.95	-.02	41.7	+0.6	98	53	-26	30	124	31	72	12.94	+1.15	83	86,458	sw.	50	sw.	140	153	72	4.0	17.4
Miles City	2,371	27.42	29.94	-.05	45.7	+1.5	98	57	-22	34	120	38	81	10.60	+2.11	73	53,023	s.	60	n.	176	127	62	4.2	13.5
Helena	4,110	25.76	29.97	-.04	43.5	+0.4	92	53	-24	34	116	27	59	10.09	+3.09	85	64,119	sw.	48	sw.	89	143	133	5.3	33.9
Kalispell	2,965	26.89	29.96	-.03	42.2	+0.7	89	52	-18	32	107	31	71	19.21	+1.80	88	45,740	w.	42	sw.	122	124	119	5.3	29.7
Rapid City	3,234	26.36	29.94	-.05	46.1	+0.1	102	58	-22	35	124	32	65	18.51	+1.80	88	71,332	nw.	46	w.	132	106	77	4.2	21.0
Cheyenne	6,088	23.97	29.92	-.05	45.0	+0.6	94	57	-27	33	121	27	57	16.50	+4.30	98	89,794	nw.	46	nw.	130	142	96	5.0	46.4
Lander	5,372	24.60	29.96	-.04	43.4	+1.0	94	58	-30	29	124	26	60	7.25	+6.46	44	33,328	sw.	42	sw.	131	196	38	4.3	40.0
North Platte	2,821	27.05	29.98	-.01	49.3	+1.4	102	61	-19	38	121	37	70	26.27	+8.00	69	76,614	se.	48	nw.	124	180	61	5.0	13.0
<i>Middle Slope.</i>																									
Denver	5,291	24.69	29.92	-.04	51.0	+1.6	100	64	-20	38	120	30	54	13.53	+1.74	70	69,379	sw.	68	nw.	147	142	76	4.6	32.3
Pueblo	4,685	25.24	29.90	-.05	51.9	+0.8	104	67	-10	37	114	30	51	10.37	+1.76	55	61,773	nw.	50	nw.	157	167	41	4.3	12.6
Concordia	1,398	28.51	29.99	-.02	52.7	+0.5	104	63	-14	43	118	42	75	35.22	+9.38	102	69,751	s.	42	s.	129	123	115	5.2	9.1
Dodge	2,509	27.36	29.95	-.03	54.5	+1.4	105	67	-11	42	116	40	70	17.70	+2.14	72	104,801	se.	53	se.	183	117	66	4.2	11.2
Wichita	1,358	28.57	30.01	-.00	53.7	+0.3	102	65	-12	46	114	44	72	38.73	+9.07	110	80,931	s.	42	n.	163	102	100	4.6	16.0
Oklahoma	1,214	28.70	29.98	-.02	59.4	+0.0	101	69	-0	50	101	48	73	41.14	+9.45	83	99,132	s.	43	n.	145	129	91	4.8	7.7
<i>Southern Slope.</i>																									
Abilene	1,738	28.16	29.96	-.02	64.7	+1.3	106	75	-10	54	96	48	63	27.05	+2.03	67	86,736	se.	53	nw.	150	124	91	4.8	4.0
Amarillo	3,676	26.22	29.91	-.05	56.4	+1.6	105	69	-4	44	109	38	60	25.11	+1.55	57	130,298	s.	67	sw.	187	128	50	3.9	0.5
<i>Southern Plateau.</i>																									
El Paso	3,762	26.14	29.85	-.04	64.3	+0.9	105	78	-24	50	81	32	40	10.15	+0.82	45	93,975	nw.	60	sw.	210	124	31	3.0	T.
Santa Fe	7,013	23.25	29.90	-.05	50.2	+1.9	91	61	-8	39	83	26	46	13.36	+0.89	78	60,000	se.	42	sw.	243	97	25	2.8	23.3
Flagstaff	6,907	23.34	29.89	-.02	44.1	+3.6	93	57	-12	31	105	33	25	8.66	+3.62	72	53,781	sw.	42	sw.	181	112	72	3.8	83.7
Phoenix	1,108	28.73	29.87	-.01	70.3	+1.2	116	85	-30	56	86	36	36	6.88	+0.05	35	37,885	e.	36	se.	233	92	40	2.8	0.0
Yuma	141	29.71	29.86	-.02	71.3	+0.9	116	86	-31	57	85	41	40	1.93	+1.04	12	54,830	w.	44	w.	311	36	18	1.1	0.0
Independence	3,910	25.94	29.91	-.03	57.6	+1.0	100	70	-10	45	90	22	29	3.83	+1.90	23	71,836	nw.	56	w.	217	114	34	3.0	T.
<i>Middle Plateau.</i>																									
Carson City	4,720	25.26	29.96	-.03	48.6	+0.8	96	62	-2	35	98	31	57	5.55	+6.42	48	59,274	sw.	64	sw.	191	110	64	3.6	29.3
Winnemucca	4,344	25.59	29.99	-.02	47.9	+0.7	97	62	-15	34	112	30	54	4.99	+3.49	51	76,479	ne.	60	sw.	165	76	124	4.8	10.5
Modena	5,479	24.58	29.92	-.03	48.1	+0.7	97	63	-18	33	115	19	42	5.09	+3.49	51	90,412	w.	58	s.	189	112	64	3.6	16.8
Salt Lake City	4,366	25.59	29.95	-.04	52.0	+0.7	98	62	-4	42	102	29	48	11.41	+4.78	75	53,265	se.	46	nw.	169	87	109	4.5	28.1
Grand Junction	4,468	25.35	29.96	-.00	52.5	+0.5	103	66	-4	39	107	25	44	6.26	+2.24	51	47,337	nw.	44	sw.	167	117	81	4.2	10.0
<i>Northern Plateau.</i>																									
Baker City	3,471	26.42	30.01	-.03	45.7	+0.8	95	56	-8	36	103	29	60	12.80	+2.35	111	51,226	se.	40	sw.	98	73	194	6.2	26.6
Boise	2,739	27.15	30.02	-.02	51.1	+0.4	102	62	-8	40	110	32	57	12.15	+2.27	84	38,244	se.	29	e.	133	113	119	5.3	22.9
Lewiston	757	29.18	30.00	-.04	53.1	+0.4	104	64	-5	43	109	33	43	13.96	+0.02	108	32,668	e.	44	sw.	131	94	140	5.3	5.9
Pocatello	4,482	25.46	29.98	-.04	47.5	+1.9	95	59	-19	36	114	29	57	11.44	+3.83	88	77,983	se.	41	sw.	131	136	78	4.6	32.5
Spokane	1,943	27.95	30.01	-.01	47.9	+0.1	94	57	-12	38	106	34	66	19.23	+0.98	127	54,029	sw.	52	w.	71	87	207	6.9	14.5
Walla Walla	1,000	28.93	30.00	-.04	52.4																				

TABLE II.—Resultant winds from observations at 8 a. m. and 8 p. m., daily, during the year 1902.

Stations.	Component direction from—				Resultant.	
	N.	S.	E.	W.	Direction from—	Duration.
<i>New England.</i>						
Eastport, Me.	238	205	119	308	n. 81 w.	190
Portland, Me.	253	234	98	298	n. 84 w.	200
Concord, N. H.	258	281	64	125	s. 27 w.	134
Northfield, Vt.	211	187	131	348	n. 85 w.	221
Boston, Mass.	220	224	162	300	s. 88 w.	136
Nantucket, Mass.	194	216	174	332	s. 82 w.	161
Block Island, R. I.	300	216	93	266	n. 65 w.	188
<i>Middle Atlantic States.</i>						
Albany, N. Y.	259	263	121	226	s. 88 w.	116
Binghamton, N. Y.†	117	50	126	139	n. 13 w.	59
New York, N. Y.	250	184	155	319	n. 68 w.	175
Harrisburg, Pa.†	149	82	155	189	n. 28 w.	74
Philadelphia, Pa.	261	211	157	271	n. 66 w.	121
Seranton, Pa.	289	204	187	238	n. 30 w.	98
Atlantic City, N. J.	255	216	141	307	n. 77 w.	165
Cape May, N. J.	244	232	149	253	n. 83 w.	105
Baltimore, Md.	238	200	151	289	n. 74 w.	137
Washington, D. C.	261	236	164	218	n. 66 w.	60
Lynchburg, Va.	217	207	195	297	n. 84 w.	100
Norfolk, Va.	226	300	214	132	s. 40 e.	97
Richmond, Va.	250	260	170	301	s. 72 w.	33
<i>South Atlantic States.</i>						
Asheville, N. C.	213	253	238	306	s. 39 e.	51
Charlotte, N. C.	191	193	224	309	s. 82 e.	15
Kittyhawk, N. C.†	253	221	167	281	n. 71 w.	99
Raleigh, N. C.	219	218	223	238	n. 86 w.	15
Wilmington, N. C.	220	214	309	243	n. 80 w.	34
Charleston, S. C.	225	222	265	211	n. 87 e.	54
Columbia, S. C.	234	207	215	247	n. 40 w.	42
Augusta, Ga.	223	197	211	259	n. 62 w.	55
Savannah, Ga.	244	221	231	217	n. 31 e.	27
<i>Florida Peninsula.</i>						
Jupiter, Fla.	178	240	251	303	s. 38 e.	78
Key West, Fla.	222	141	430	87	n. 77 e.	352
Tampa, Fla.	280	143	269	209	n. 23 e.	151
<i>Eastern Gulf States.</i>						
Atlanta, Ga.	230	215	205	243	n. 69 w.	41
Macon, Ga.†	141	109	78	109	n. 44 w.	45
Pensacola, Fla.†	167	71	120	92	n. 16 e.	100
Mobile, Ala.	290	247	146	187	n. 44 w.	59
Montgomery, Ala.	221	218	238	206	n. 86 e.	32
Meridian, Miss.†	124	102	112	109	n. 8 e.	22
Vicksburg, Miss.	290	252	278	161	s. 66 e.	127
New Orleans, La.	237	270	248	157	s. 70 e.	96
<i>Western Gulf States.</i>						
Shreveport, La.	169	308	278	148	s. 43 e.	191
Fort Smith, Ark.	151	163	376	148	s. 87 e.	229
Little Rock, Ark.	215	263	213	206	s. 8 e.	48
Corpus Christi, Tex.	161	328	378	54	s. 62 e.	365
Fort Worth, Tex.	167	369	210	143	s. 18 e.	210
Galveston, Tex.	160	341	315	98	s. 49 e.	282
Palestine, Tex.	188	338	239	109	s. 41 e.	198
San Antonio, Tex.	181	286	395	66	s. 73 e.	346
Taylor, Tex.†	104	188	68	60	s. 5 e.	84
<i>Ohio Valley and Tennessee.</i>						
Chattanooga, Tenn.	242	210	180	261	n. 68 w.	86
Knoxville, Tenn.	294	195	132	284	n. 57 w.	182
Memphis, Tenn.	247	257	309	199	s. 45 e.	14
Nashville, Tenn.	254	244	172	231	n. 81 w.	60
Lexington, Ky.†	73	157	99	119	s. 13 w.	43
Louisville, Ky.	223	262	157	224	s. 60 w.	77
Evansville, Ind.†	120	135	108	83	s. 59 e.	29
Indianapolis, Ind.	240	271	132	240	s. 74 w.	112
Cincinnati, Ohio.	205	227	238	263	s. 47 w.	33
Columbus, Ohio.	182	248	187	275	s. 53 w.	110
Pittsburg, Pa.	274	210	155	294	n. 65 w.	152
Parkersburg, W. Va.	213	245	168	245	s. 68 w.	83
Elkins, W. Va.	214	194	80	333	n. 85 w.	254
<i>Lower Lake Region.</i>						
Buffalo, N. Y.	141	238	160	336	s. 61 w.	201
Oswego, N. Y.	157	313	159	247	s. 29 w.	179
Rochester, N. Y.	131	267	140	366	s. 59 w.	269
Syracuse, N. Y.	203	216	121	326	s. 87 w.	200
Erie, Pa.	190	296	190	225	s. 77 w.	112
Cleveland, Ohio.	84	133	78	160	s. 60 w.	97
Sandusky, Ohio†	168	241	175	306	s. 61 w.	150
Toledo, Ohio.	209	213	179	299	s. 88 w.	120
<i>Upper Lake Region.</i>						
Alpena, Mich.	234	218	170	283	n. 82 w.	113
Escanaba, Mich.	256	256	108	263	w.	155
Grand Haven, Mich.	220	236	179	259	s. 79 w.	82
Houghton, Mich.†	94	67	134	137	n. 6 w.	27
Marquette, Mich.	249	210	120	318	n. 79 w.	204
Port Huron, Mich.	240	240	148	274	w.	126
Sault Ste. Marie, Mich.	188	191	236	282	s. 86 w.	46
Chicago, Ill.	213	241	188	282	s. 69 w.	79
Milwaukee, Wis.	215	204	155	315	s. 86 w.	60
Green Bay, Wis.	196	293	169	257	s. 42 w.	130
Duluth, Minn.	343	125	203	290	n. 22 w.	235
<i>North Dakota.</i>						
Moorhead, Minn.	262	240	217	233	n. 36 w.	27
Bismarck, N. Dak.	295	165	226	212	n. 26 e.	131
Williston, N. Dak.	282	219	144	309	n. 46 w.	92
<i>Upper Mississippi Valley.</i>						
St. Paul, Minn.	222	262	179	236	s. 43 w.	83
La Crosse, Wis.†	113	174	58	77	s. 17 w.	64
Davenport, Iowa.	222	262	179	236	s. 43 w.	83
Des Moines, Iowa.	214	246	214	236	s. 34 w.	39
Dubuque, Iowa.	226	253	192	252	s. 66 w.	66
Keokuk, Iowa.	215	254	186	263	s. 63 w.	87
Cairo, Ill.	238	288	189	180	s. 10 e.	51
Springfield, Ill.	202	259	162	282	s. 65 w.	133
Hannibal, Mo.†	96	137	90	124	s. 39 w.	58
St. Louis, Mo.	210	317	137	193	s. 28 w.	122
<i>Missouri Valley.</i>						
Columbia, Mo.†	104	139	113	92	s. 31 e.	41
Kansas City, Mo.	224	305	206	153	s. 34 e.	97
Springfield, Mo.	183	354	226	164	s. 23 e.	163
Topeka, Kans.	252	290	204	131	s. 62 e.	81
Lincoln, Nebr.	241	287	198	164	s. 36 e.	57
Omaha, Nebr.	237	207	163	273	n. 74 w.	114
Sioux City, Iowa†	130	133	106	95	s. 75 e.	11
Pierre, S. Dak.	248	204	269	162	n. 67 e.	116
Huron, S. Dak.	254	253	226	180	n. 89 e.	56
Yankton, S. Dak.†	187	176	186	370	n. 87 w.	187
<i>Northern Slope.</i>						
Havre, Mont.	228	222	154	252	n. 86 w.	98
Miles City, Mont.	137	270	82	439	s. 70 w.	379
Helena, Mont.	117	303	121	435	s. 74 w.	324
Kalispell, Mont.	254	148	177	310	n. 51 w.	169
Rapid City, S. Dak.	248	305	82	347	n. 81 w.	268
Cheyenne, Wyo.	184	278	169	286	s. 54 w.	157
Lander, Wyo.	181	235	226	250	s. 24 w.	59
<i>Middle Slope.</i>						
Denver, Colo.	232	278	201	180	s. 25 e.	51
Pueblo, Colo.	278	163	226	225	n. 89 e.	115
Concordia, Kans.	196	328	154	135	s. 20 w.	141
Dodge, Kans.	236	252	279	150	s. 83 e.	129
Wichita, Kans.	231	354	185	84	s. 39 e.	160
Oklahoma, Okla.	210	356	191	83	s. 40 e.	166
<i>Southern Slope.</i>						
Abilene, Tex.	179	355	284	116	s. 44 e.	243
Amarillo, Tex.	170	382	164	187	s. 6 w.	211
<i>Southern Plateau.</i>						
El Paso, Tex.	252	91	244	321	n. 25 w.	177
Santa Fe, N. Mex.	211	261	273	158	s. 67 e.	125
Flagstaff, Ariz.	205	301	127	357	n. 89 w.	232
Phoenix, Ariz.	135	131	308	281	n. 82 e.	27
Yuma, Ariz.	223	207	177	250	n. 77 w.	74
Independence, Cal.	251	227	141	304	n. 81 w.	166
<i>Middle Plateau.</i>						
Carson City, Nev.	156	260	98	351	s. 68 w.	276
Winnemucca, Nev.	239	198	190	235	n. 69 w.	111
Modena, Utah	108	227	113	429	s. 69 w.	337
Salt Lake City, Utah.	252	233	265	175	n. 78 e.	92
Grand Junction, Colo.	219	186	266	256	n. 17 e.	34
<i>Northern Plateau.</i>						
Baker City, Oreg.	293	349	214	187	s. 10 e.	149
Boise, Idaho.	184	218	221	289	s. 63 w.	76
Lewiston, Idaho†	25	89	230	68	s. 68 e.	174
Pocatello, Idaho.	66	332	228	278	s. 10 w.	270
Spokane, Wash.	143	315	236	185	s. 17 e.	180
Walla Walla, Wash.	81	471	67	198	s. 19 w.	410
<i>North Pacific Coast Region.</i>						
North Head, Wash.	5	79	124	205	s. 48 w.	110
Port Crescent, Wash.*	201	300	240	144	s. 44 e.	138
Seattle, Wash.	237	300	81	248	s. 21 w.	179
Tacoma, Wash.	206	270	167	253	s. 53 w.	107
Tatoosh Island, Wash.	254	186	171	239	n. 45 w.	96
Astoria, Oreg.	206	270	167	253	s. 53 w.	107
Portland, Oreg.	254	186	171	239	n. 45 w.	96
<i>Middle Pacific Coast Region.</i>						
Eureka, Cal.	227	275	154	222	s. 55 w.	83
Mount Tamalpais, Cal.	292	167	73	397	n. 69 w.	343
Red Bluff, Cal.	294	264	227	103	n. 76 e.	127
Sacramento, Cal.	131	405	260	108	s. 29 e.	314
San Francisco, Cal.	98	186	73	485	s. 79 w.	422
<i>South Pacific Coast Region.</i>						
Fresno, Cal.	330	82	123	399	n. 48 w.	371
Los Angeles, Cal.	163	136	169	388	n. 83 w.	220
San Diego, Cal.	304	130	125	345	n. 51 w.	238
San Luis Obispo, Cal.	266	140	25	324	n. 67 w.	325
<i>West Indies.</i>						
Basseterre St. Kitts, W. I.	169	74	584	14	n. 80 e.	578
Bridgetown, Barbados.	88	95	652	2	s. 89 e.	650
Havana, Cuba.	171	96	517	50	n. 81 e.	471
Puerto Principe, Cuba.	298	69	486	44	n. 62 e.	496
San Juan, Porto Rico.	35	307	493	35	s. 60 e.	533
Santiago de Cuba, Cuba.	472	136	166	78	n. 16 e.	350

\* From observations at 8 p. m. only. † From observations at 8 a. m. only. ‡ From observations at 8 a. m. only to August, inclusive, and from both 8 a. m. and 8 p. m. observations for the remainder of the year.

TABLE III.—Total number of days with thunderstorms at selected stations, 1902.

State and station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Alabama.													
Mobile	0	4	3	2	6	4	11	7	4	3	0	1	45
Montgomery	2	3	7	2	10	5	13	9	3	1	0	2	57
Scottsboro	0	3	5	2	5	11	16	9	3	1	0	0	55
Arizona.													
Flagstaff	0	0	1	0	0	0	2	8	0	0	0	0	11
Fort Defiance	0	0	0	0	0	0	0	4	0	0	1	0	5
Phoenix	0	0	0	0	0	1	5	5	6	0	0	0	17
Showlow	0	0	0	0	3	1	3	7	7	0	1	0	22
Yuma	0	0	0	0	0	0	2	0	0	0	0	0	0
Arkansas.													
Blanchard	3	3	4	4	5	2	4	0	0	0	2	2	29
Little Rock	1	2	8	8	4	11	5	4	4	1	1	1	50
Pocahontas	1	3	2	6	6	10	3	7	2	0	1	1	42
Fort Smith	0	2	4	5	8	6	6	8	7	2	3	1	52
California.													
Eureka	0	3	1	0	0	0	0	0	0	0	1	0	5
Fresno	0	0	1	1	0	0	0	1	0	0	0	1	4
Independence	0	0	0	1	0	1	2	5	1	0	0	0	10
Los Angeles	0	0	0	0	0	2	0	0	0	0	0	0	2
Mount Tamalpais	0	0	1	0	0	0	0	0	0	0	0	0	1
Red Bluff	0	0	0	1	0	0	0	0	0	1	0	0	2
Sacramento	0	0	0	0	0	0	0	2	0	0	0	1	3
San Diego	1	0	0	0	1	2	0	0	0	0	0	0	4
San Francisco	0	0	0	0	0	0	0	1	0	1	0	0	2
San Luis Obispo	1	1	0	0	1	0	0	0	0	0	0	0	3
Colorado.													
Denver	0	1	1	1	8	8	3	13	1	2	0	0	39
Durango	0	0	0	0	0	0	0	0	0	1	1	0	2
Grand Junction	0	0	0	2	3	2	7	8	1	3	0	0	26
Pueblo	0	0	1	0	7	9	7	14	1	1	0	0	40
Connecticut.													
Hartford	0	1	1	2	2	6	7	3	2	0	0	2	26
New Haven	0	1	0	1	3	5	9	7	2	1	0	0	29
District of Columbia.													
Washington	0	1	1	2	9	7	14	9	3	1	1	0	48
Florida.													
Jacksonville	0	3	6	5	9	11	20	13	13	2	1	3	86
Jupiter	0	4	1	5	7	8	16	11	11	10	3	1	77
Key West	0	2	0	4	3	2	5	6	2	5	1	0	30
Merritt Island	0	2	4	2	6	14	23	24	26	13	3	0	117
Myers	0	2	1	1	14	17	31	24	31	18	2	1	142
Pensacola	0	4	6	2	8	8	16	15	7	2	2	3	73
Tampa	0	3	2	2	9	6	13	15	13	3	0	1	67
Georgia.													
Atlanta	0	2	5	4	12	7	14	15	4	0	1	0	64
Augusta	0	1	1	3	5	6	10	12	3	0	0	0	41
Clayton	0	1	1	1	16	9	16	8	2	0	0	0	54
Macon	0	1	3	4	10	5	13	10	3	0	0	1	50
Poulan	0	4	4	2	5	5	7	4	1	1	1	0	34
Savannah	1	2	3	5	8	9	20	9	6	1	1	2	67
Idaho.													
Boise	0	0	0	0	1	1	1	2	1	0	0	1	7
Downey	0	0	0	0	4	2	1	0	0	0	0	0	7
Lewiston	0	0	0	2	2	2	1	3	0	0	0	0	10
Murray	0	0	0	1	1	2	0	0	0	0	0	0	4
Ola	0	1	0	1	3	1	0	0	0	0	0	0	6
Pocatello	0	0	0	0	2	1	3	5	0	0	0	0	11
Illinois.													
Cairo	0	1	6	7	8	8	6	10	2	0	1	1	50
Chicago	0	0	1	1	14	10	9	4	2	3	0	0	44
Cine	0	0	1	2	9	10	6	4	0	0	0	0	32
Peoria	0	0	0	3	0	4	8	4	5	3	0	0	27
Rantoul	0	0	3	5	6	14	13	8	5	2	0	0	56
Springfield	0	0	4	8	10	11	10	8	4	1	2	1	59
Winnebago	0	0	1	2	1	0	9	2	2	1	0	0	18
Indiana.													
Butler	0	1	2	2	6	7	5	4	2	2	2	0	33
Cambridge City	0	0	2	5	12	11	8	3	2	1	1	1	47
Evansville	0	0	3	6	7	12	6	6	2	1	0	2	45
Huntington	0	0	3	3	6	7	9	2	4	5	0	1	40
Indianapolis	0	0	2	3	8	10	8	3	1	3	2	1	41
Worthington	0	0	2	2	6	10	6	4	2	1	0	1	34
Iowa.													
Davenport	0	0	0	2	11	10	14	6	2	4	0	0	49
Des Moines	0	0	4	3	11	11	11	12	2	5	1	0	60
Dubuque	0	0	3	3	11	11	10	4	4	4	0	0	50
Keokuk	0	0	1	5	8	11	12	10	3	2	1	0	53
Sioux City	0	0	2	3	4	6	11	6	3	1	0	0	36
Kansas.													
Concordia	0	0	1	3	6	14	11	13	3	2	1	0	54
Dodge	0	0	2	0	9	10	9	9	3	1	2	0	45
Topeka	0	0	4	3	10	7	7	12	2	2	0	0	47
Wichita	0	0	1	3	12	12	9	10	7	0	1	0	55
Kentucky.													
Lexington	0	0	1	1	9	10	9	7	0	2	0	2	41
Louisville	1	1	1	4	9	12	10	6	1	2	0	1	48
Louisiana.													
Grand Coteau	0	3	3	2	2	1	1	4	0	0	0	2	18
New Orleans	0	4	4	4	7	5	19	13	11	1	1	3	72
Shreveport	1	1	3	7	8	2	15	3	6	2	2	2	52
Maine.													
Eastport	0	0	0	1	2	3	3	3	0	1	0	0	13
Farmington	0	1	2	5	1	1	5	2	1	0	0	0	19
Orono	0	0	1	3	2	0	1	3	0	1	0	0	11
Portland	0	1	0	1	2	3	2	3	1	1	0	0	14
Maryland.													
Baltimore	1	1	1	2	4	7	11	8	2	0	1	0	38
Grantsville	0	1	1	2	9	10	13	6	2	0	0	0	44
Princess Anne	0	1	3	2	6	4	9	6	1	1	0	0	33
Massachusetts.													
Boston	0	0	0	2	1	3	3	6	0	0	0	0	15

TABLE III.—Total number of days with thunderstorms, etc.—Continued.

State and station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
<i>Massachusetts—Con.</i>													
Monson	0	0	0	0	3	0	5	3	0	0	0	0	10
Nantucket	0	0	0	1	1	2	3	6	1	0	0	0	14
New Bedford	0	0	0	2	0	1	2	5	0	1	0	0	11
Williamstown	0	0	1	4	1	1	1	3	0	1	0	0	12
<i>Michigan.</i>													
Alpena	0	0	1	1	7	6	9	4	3	1	0	0	32
Detroit	0	0	3	3	9	8	14	4	2	3	0	0	46
Escanaba	0	0	0	1	3	4	8	2	2	0	1	0	21
Grand Haven	0	0	1	2	11	8	10	2	2	2	0	0	38
Houghton	0	0	1	2	3	2	6	1	2	3	0	0	20
Lansing	0	0	2	2	8	9	12	1	2	4	0	0	40
Marquette	0	0	0	2	1	2	7	0	0	1	0	0	13
Port Huron	0	0	0	2	9	5	11	3	2	4	0	0	36
Sault Ste. Marie	0	0	0	0	2	2	6	1	3	0	0	0	14
<i>Minnesota.</i>													
Duluth	0	0	1	2	4	3	10	6	3	3	0	0	32
Minneapolis	0	0	1	3	8	5	10	6	5	4	0	0	42
Moorhead	0	0	2	2	7	6	6	0	2	0	0	0	31
Rolling Green	0	0	0	1	2	1	5	2	1	0	0	0	12
St. Cloud	0	0	0	2	5	3	8	3	3	2	0	0	26
St. Paul	0	0	0	2	8	3	11	5	5	3	0	0	37
<i>Mississippi.</i>													
Biloxi	0	3	3	1	3	5	5	5	1	1	0	1	28
Meridian	0	3	8	4	6	3	14	11	2	2	0	1	54
Vicksburg	0	2	7	6	8	5	17	7	7	2	1	1	63
Water Valley	0	4	5	2	5	6	4	1	3	0	0	1	31
<i>Missouri.</i>													
Columbia	0	0	2	4	13	15	10	13	5	2	1	0	65
Hannibal	0	0	1	7	11	10	7	12	3	3	0	1	55
Kansas City	0	0	3	3	9	10	9	12	6	1	0	0	53
St. Louis	0	0	5	5	9	9	10	10	3	4	1	2	58
Springfield	0	1	4	5	9	13	11	9	4	3	0	1	60
<i>Montana.</i>													
Hayre	0	0	0	0	4	6	2	4	0	0	0	0	16
Helena	0	0	0	0	9	4	3	8	0	0	0	0	24
Kalispell	0	0	0	0	3	3	2	2	1	0	0	0	11
Miles City	0	0	0	0	6	4	2	4	0	0	0	0	16
Ovando	0	0	0	0	3	1*	2	5	0	1	0	0	12
Parrot	0	0	0	1	3	3	2	0†	0	1	0†	0	10
<i>Nebraska.</i>													
Lincoln	0	0	4	4	9	10	16	8	4	3	1	0	59
North Platte	0	0	1	2	8	8	9	8	0	1	0	0	37
Omaha	0	0	5	3	11	9	16	11	5	3	1	0	64
Valentine	0	0	2	2	3	8	6	12	2	0	0	0	35
<i>Nevada.</i>													
Belmont	0	0	0	0	0	0	1	5	1	0	0	0	7
Carson City	0	0	0	0	0	0	0	4	2	0	0	0	6
Winnemucca	0	0	1	0	0	0	0	3	0	0	0	0	4
<i>New Hampshire.</i>													
Bethlehem	0	0	0	2	2	1	2	1	1	2	0	0	11
Nashua	0	0	0	2	3	3	1	4	1	1	0	0	15
<i>New Jersey.</i>													
Atlantic City	0	1	1	2	3	8	8	6	3	1	1	0	34
Cape May	0	1	3	2	5	7	8	6	1	0	0	0	33
Somerville	0	1	1	0	2	4	10	11	1	0	0	0	30
<i>New Mexico.</i>													
Roswell	0	0	0	0	5	3	8	9	0	2	0	0	27
Santa Fe	0	0	1	1	9	4	16	11	5	2	0	0	49
<i>New York.</i>													
Albany	0	0	1	2	1	5	7	5	2	5	0	0	28
Binghamton	0	1	2	0	6	8	12	8	4	2	0	0	43
Buffalo	0	0	1	1	4	2	8	6	3	6	0	0	31
New York	0	0	0	1	1	8	9	6	0	0	0	0	25
Oswego	0	0	0	3	5	8	9	5	2	5	0	0	35
Rochester	0	0	0	2	3	7	8	2	1	4	0	0	27
South Canistota	0	1	1	0	6	3	12	6	1	4	0	0	34
<i>North Carolina.</i>													
Asheboro	0	0	1	1	10	13	11	10	3	0	1	0	56
Charlotte	0	2	5	3	7	8	12	11	4	1	0	0	53
Hatteras	0	2	2	1	5	7	3	7	1	1	1	0	36
Raleigh	0	1	1	2	7	9	10	9	5	0	0	0	40
Wilmington	1	2	3	2	8	10	7	10	5	0	1	0	49
<i>North Dakota.</i>													
Amenia	0	0	0	0	4	2	3	3	0	1	0	0	13
Rismarck	0	0	0	1	5	9	8	7	1	2	0	0	33
Williston	0	0	0	0	2	3	1	4	0	1	0	0	11
<i>Ohio.</i>													
Cincinnati	0	1	1	3	7	14	8	4	1	2	0	0	41
Cleveland	0	0	1	2	4	10	14	4	2	3	0	0	40
Columbus	0	1	3	1	4	10	7	3	4	2	0	0	35
Sandusky	0	0	2	0	6	7	11	3	2	1	0	0	32
Toledo	0	0	0	1	8	9	12	4	4	3	0	0	41
<i>Oklahoma.</i>													
Oklahoma	0	0	3	5	11	6	5	6	4	0	3	0	43
Perry	0	0	1	3	6	4	1	2	0	0	0	0	17
<i>Oregon.</i>													
Astoria	1	1	0	0	0	0	0	0	0	0	0	0	2
Baker City	0	0	0	0	4	0	1	2	0	0	0	0	7
Portland	0	0	0	0	1	0	2	1	0	0	0	0	4
Roseburg	0	0	0	1	1	0	0	0	0	0	0	0	2
<i>Pennsylvania.</i>													
Erie	0	1	0	0	8	4	8	3	1	3	0	0	28
Harrisburg	0	1	1	0	4	5	15	6	1	0	0	0	33
Philadelphia	0	1	3	1	3	8	13	9	0	1	0	0	39
Pittsburg	0	0	2	3	8	6	11	5	2	0	0	0	37
Seranton	0	1	0	0	4	7	11	6	0	0	0	0	29
Wellshoro	0	0	1	0	4	5	9	5	2	2	0	0	28
<i>Rhode Island.</i>													
Block Island	0	1	0	2	1	3	6	4	2	0	0	0	19
Narragansett	0	0	0	2	1	2	1	4	2	0	0	0	12
<i>South Carolina.</i>													
Charleston	0	4	3	6	11	11	24	18	8	0	0	2	87
Columbia	0	2	2	6	8	7	12	15	2	0	1	0	55



TABLE VI.—Annual climatological summary—Continued.

Stations.	Pressure.*			Temperature.				Precipitation.		Total depth of snow-fall, †
	Mean not reduced.	Mean reduced.	Departure from normal.	Mean.	Departure from normal.	Mean maximum.	Mean minimum.	Total.	Departure from normal.	
	Inch.	Inch.	Inch.	°	°	°	°	Inch.	Inch.	Inch.
Chatham, N. B.	29.87	29.89	-.05	41.2	+2.5	51.3	31.0	46.65	+5.36	108.4
Father Point, Que.	29.88	29.90	-.03	36.7	+1.9	44.4	29.0	44.23	+11.24	123.9
Quebec, Que.	29.61	29.94	-.04	39.7	+1.5	47.7	31.7	46.39	+4.67	104.3
Montreal, Que.	29.75	29.96	-.03	43.0	+1.5	50.4	35.6	46.16	+5.17	119.2
Bissett, Ont.	29.37	29.99	-.00	38.6	+0.4	51.0	26.2	32.94	+2.48	52.4
Ottawa, Ont.	29.69	30.02	-.02	42.6	+2.0	51.6	33.6	35.96	+3.36	98.9
Kingston, Ont.	29.65	29.97	-.04	44.2	+1.1	52.2	36.3	30.44	+2.37	37.4
Toronto, Ont.	29.60	29.98	-.04	46.0	+1.8	54.5	37.4	31.07	+2.65	51.6
White River, Ont.	28.64	29.98	-.00	34.0	+2.1	46.4	21.6	28.49	+3.70	104.0
Port Stanley, Ont.	29.35	29.90	-.03	45.4	+0.7	53.7	37.2	42.59	+8.17	85.4
Saugeen, Ont.	29.27	29.99	-.02	44.8	+2.4	53.1	36.5	34.72	+6.51	78.3
Parry Sound, Ont.	29.27	29.97	-.03	42.6	+2.4	52.4	32.8	45.23	+6.96	133.1
Port Arthur, Ont.	29.26	29.98	-.02	37.0	+2.6	45.8	28.1	21.82	+2.94	14.6
Winnipeg, Man.	29.12	29.96	-.04	37.6	+4.5	48.6	26.6	20.92	+0.06	31.2
Minnedosa, Man.	28.14	29.99	-.01	36.0	+4.4	47.2	24.8	19.30	+2.85	40.6
Qu'Appelle, Assin.	27.66	29.95	-.03	35.7	+2.4	45.9	25.5	24.37	+8.29	100.8
Medicine Hat, Assin.	27.63	29.93	-.03	41.4	+1.1	54.0	28.9	13.68	+0.12	26.8
Swift Current, Assin.	27.35	29.96	-.01	38.4	+0.9	49.0	27.8	17.64	+2.17	36.8
Calgary, Alberta.	26.32	29.89	-.04	37.0	+0.2	48.1	25.8	34.57	+19.70	82.0
Banff, Alberta.	25.28	29.92	-.01	34.8	+0.1	45.4	24.2	30.59	+8.68	98.9
Edmonton, Alberta.	27.58	29.90	-.03	36.9	+1.3	47.5	26.3	20.66	+4.83	50.7
Prince Albert, Sask.	28.34	29.92	-.06	33.2	+2.7	44.4	22.1	20.01	+5.10	41.0
Battleford, Sask.	28.19	29.96	-.01	34.3	+1.6	45.4	23.2	13.49	+0.44	30.9
Kamloops, B. C.	28.68	29.90	-.03	47.2	+0.1	56.9	37.4	14.10	+2.47	13.2
Victoria, B. C.	29.89	29.99	-.01	50.2	+1.6	55.9	44.5	26.45	+11.69	11.0
Barkerville, B. C.	25.57	29.89	-.01	35.5	+0.7	45.4	25.6	32.23	+1.33	134.0
Hamilton, Bermuda.	29.82	29.98	-.11	69.6	+0.1	74.6	64.5	87.64	+25.73	0.0

\* Reduced to standard gravity and to the mean of twenty-four hourly observations. † For the snow year, July 1, 1901, to June 30, 1902.

TABLE VII.—Heights of rivers referred to zeros of gages, 1902.

Stations.	Highest water.		Lowest water.		Mean stage.	Annual range.
	Stage.	Date.	Stage.	Date.		
<i>Mississippi River.</i>	Feet.		Feet.		Feet.	Feet.
St. Paul, Minn. (1)	7.5	May 26, 27	1.1	Mar. 10	3.1	6.4
Reeds Landing, Minn.	5.4	Nov. 19, 20	—0.6	Feb. 18, 23	1.9	6.0
La Crosse, Wis. (2)	7.7	May 23	1.4	Aug. 30	3.6	6.3
Prairie du Chien, Wis. (1)	10.8	May 24	0.9	Aug. 31, Sept. 1	4.0	9.9
Dubuque, Iowa (2)	12.6	May 24	1.6	Sept. 1-3	4.8	11.0
Leclaire, Iowa (2)	8.0	May 26, 27	0.8	Sept. 3-5	3.0	7.2
Davenport, Iowa (2)	10.4	May 26-28	1.8	Sept. 3-5	4.4	8.6
Muscatine, Iowa	12.0	May 28, 29	2.3	Sept. 4-6	5.0	9.7
Galland, Iowa (2)	7.5	July 21, 22	1.0	Apr. 23, 24; May 2, 3	3.2	6.5
Keokuk, Iowa (2)	15.5	July 21	1.0	Apr. 23, 24; May 2	5.7	14.5
Hannibal, Mo. (2)	16.6	July 23	1.9	Apr. 23, 24	6.8	14.7
Grafton, Ill.	20.4	July 26	0.8	Jan. 29	8.7	19.6
St. Louis, Mo. (2)	26.9	July 26	—1.2	Jan. 30	13.6	28.1
Chester, Ill.	22.8	July 27	—1.4	Jan. 30, 31	10.1	24.2
New Madrid, Mo.	33.2	Mar. 17, 18	6.9	Sept. 27	18.2	26.3
Memphis, Tenn.	30.8	Mar. 20, 21	3.0	Sept. 28, 29	14.6	27.8
Helena, Ark.	39.6	Mar. 23, 24	6.3	Sept. 30	21.0	33.3
Arkansas City, Ark.	41.4	Mar. 28, 29	6.8	Oct. 1	23.3	34.6
Greenville, Miss.	36.0	Mar. 29	6.0	Oct. 1	19.4	30.0
Vicksburg, Miss.	41.2	Apr. 17, 18	4.8	Oct. 3	21.6	36.4
New Orleans, La.	14.9	Apr. 19	3.6	Nov. 15	7.6	11.3
<i>Missouri River.</i>						
Bismarck, N. Dak.	9.6	Mar. 19, 20	0.4	Feb. 15, Oct. 15, 16	3.7	9.2
Pierre, S. Dak. (1)	9.2	June 10	—0.2	Dec. 1-4	4.4	9.4
Sioux City, Iowa (1)	12.4	June 12	4.7	Mar. 19, Nov. 30, Dec. 2-4	8.1	7.7
Omaha, Nebr. (1)	12.4	June 14	4.4	Dec. 4	8.4	8.0
St. Joseph, Mo.	9.4	July 13	—2.1	Dec. 16	3.4	11.5
Kansas City, Mo. (2)	23.2	July 15	3.5	Dec. 15	10.9	19.7
Booneville, Mo. (2)	18.6	July 15, 16	4.8	Dec. 19	10.1	13.8
Hermann, Mo. (2)	18.0	July 3	1.7	Jan. 29	9.7	16.3
<i>Illinois River.</i>						
Peoria, Ill.	21.0	July 22	6.8	Jan. 23-27	11.9	14.2
<i>Youghiogheny River.</i>						
Confluence, Pa.	10.1	Feb. 28	0.3	Sept. 21-25; Nov. 11-24	2.0	9.8
<i>West Newton, Pa. (2)</i>	22.0	Feb. 28	0.0	Sept. 4-6, 16-24, 26, 27	2.3	22.0
<i>Allegheny River.</i>						
Warren, Pa.	13.5	Mar. 2	—0.3	Sept. 21-30	2.0	13.8
Oil City, Pa.	15.3	Mar. 2	0.2	Sept. 22-24	3.0	15.1
Parker, Pa.	18.0	Mar. 1, 2	—0.2	Sept. 18-24	2.9	18.2
<i>Monongahela River.</i>						
Weston, W. Va.	11.2	Jan. 27	—1.2	Oct. 25-27	0.6	12.4
Fairmont, W. Va.	18.8	Dec. 13	0.7	Sept. 19-26	3.1	18.1
Greensboro, Pa.	22.7	Mar. 1	6.0	Sept. 19-21	8.6	16.7
Lock No. 4, Pa.	29.5	Mar. 1	5.9	Sept. 30, Oct. 29	9.6	23.6
<i>Onondaga River.</i>						
Johnstown, Pa.	10.8	Mar. 1	0.4	Sept. 21-24	2.4	10.4
<i>Red Bank Creek.</i>						
Brookville, Pa.	6.7	Mar. 1	—0.5	Sept. 20-Nov. 23	0.8	7.2

TABLE VII.—Heights of rivers referred to zeros of gages, 1902—Continued.

Stations.	Highest water.		Lowest water.		Mean stage.	Annual range.
	Stage.	Date.	Stage.	Date.		
<i>Beaver River.</i>	Feet.		Feet.		Feet.	Feet.
Ellwood Junction, Pa. (2)	10.0	Mar. 1	2.1	Sept. 7-29	3.6	7.9
<i>Great Kanawha River.</i>						
Charleston, W. Va.	33.0	Mar. 1	3.8	June 3	7.4	29.2
<i>Little Kanawha River.</i>						
Glenville, W. Va.	16.2	Dec. 16	—2.6	Nov. 10-12	1.0	18.8
<i>New River.</i>						
Hinton, W. Va.	17.0	Mar. 1	1.0	Sept. 1-5	2.7	16.0
<i>Cheat River.</i>						
Rowlesburg, W. Va. (1)	10.0	Mar. 1	—0.4	Sept. 25	3.1	10.4
<i>Ohio River.</i>						
Pittsburg, Pa.	30.3	Mar. 2	1.2	Jan. 15	6.9	29.1
Davis Island Dam, Pa.	29.0	Mar. 2	1.7	Sept. 20	6.5	27.3
Wheeling, W. Va.	42.0	Mar. 2, 3	1.1	Sept. 22	8.6	40.9
Parkersburg, W. Va.	40.0	Mar. 4	1.9	Sept. 24-26	9.7	38.1
Point Pleasant, W. Va.	46.3	Mar. 3	1.0	Sept. 25, 26	10.9	45.3
Huntington, W. Va.	49.5	Mar. 3	3.3	Sept. 22-26	14.5	46.2
Catlettsburg, Ky.	50.6	Mar. 2	0.8	Sept. 23-25	13.8	49.6
Portsmouth, Ohio	50.3	Mar. 3, 4	2.5	Sept. 25, 26	15.0	47.8
Cincinnati, Ohio	50.9	Mar. 5	3.9	Sept. 24, 25	16.8	47.0
Madison, Ind.	41.8	Mar. 8	3.5	Sept. 27	15.1	38.3
Louisville, Ky.	24.8	Mar. 9	2.7	Sept. 7, 8	7.8	22.1
Evansville, Ind.	40.0	Mar. 11, Dec. 22	1.7	Sept. 24	13.9	38.3
Paducah, Ky.	39.7	Mar. 15, 16	1.4	Sept. 17, 18, 23-26	14.3	38.3
Cairo, Ill.	42.2	Mar. 17	7.3	Sept. 26	22.0	34.9
<i>Muskingum River.</i>						
Zanesville, Ohio	17.2	Dec. 17	5.3	Sept. 18-24	7.9	11.9
<i>Savannah River.</i>						
Columbus, Ohio (2)	9.0	Dec. 17	2.0	Apr. 30-May 23	3.0	7.0
<i>Miami River.</i>						
Dayton, Ohio	6.7	Dec. 17	0.1	Sept. 7-14, 17, 20-25	1.4	6.6
<i>Wabash River.</i>						
Mt. Carmel, Ill. (2)	17.0	Dec. 25	1.0	Sept. 25, 26	5.4	16.0
<i>Licking River.</i>						
Falmouth, Ky.	28.2	Dec. 16	0.1	Sept. 4-13, 18-23	3.7	28.1
<i>Kentucky River.</i>						
Frankfort, Ky.	28.8	Jan. 31	5.0	Sept. 18-27	7.8	23.8
<i>Clinch River.</i>						
Speer's Ferry, Va.	23.6	Mar. 1	—0.8	Aug. 30, 31	1.0	24.2
Clinton, Tenn.	32.5	Mar. 2	2.4	Sept. 11-14, 18	6.4	30.1
<i>Holston River.</i>						
Rogersville, Tenn. (1)	10.6	Mar. 30	1.3	Oct. 25	2.4	9.3
<i>Tennessee River.</i>						
Knoxville, Tenn.	36.1	Mar. 1	0.3	Sept. 2; Oct. 24-28	3.3	35.8
Kingston, Tenn.	28.3	Mar. 2	1.0	Aug. 15-20	3.9	27.3
Chattanooga, Tenn.	40.8	Jan. 2	1.2	Aug. 22-Sept. 11	6.4	39.6
Bridgeport, Ala.	27.7	Jan. 3	0.2	Oct. 30, 31	4.5	27.5
Flomberg, Ala.	22.5	Mar. 29	—0.3	Sept. 3-5	4.8	22.8
Riverton, Ala.	33.2	Mar. 10	—1.5	Oct. 30-Nov. 1	6.6	34.7
Johnsonville, Tenn.	35.6	Apr. 2, 3	0.4	Nov. 1-5	8.5	35.2
<i>Cumberland River.</i>						
Burnside, Ky.	58.9	Mar. 30	0.6	Aug. 4-5	5.8	58.3
Carthage, Tenn.	50.4	Mar. 31	—0.4	Nov. 16	7.3	50.8
Nashville, Tenn.	46.1	Apr. 5	1.0	Sept. 17, 18, 22, 23	10.1	45.1
Clarksville, Tenn.	50.6	Apr. 5	0.1	Sept. 15, 16	12.9	50.5
<i>Arkansas River.</i>						
Wichita, Kans. (1)	5.9	June 3	0.8	Jan. 22, 23	1.8	5.1
Webbers Falls, Ind. T.	18.1	May 25	1.5	Aug. 22-25	5.9	16.6
Fort Smith, Ark.	19.0	May 23	—0.2	Jan. 30, Feb. 11	6.1	19.2
Dardanelle, Ark.	17.8	May 26	0.3	Jan. 30-Feb. 14-20	5.9	17.5
Little Rock, Ark.	19.2	Dec. 19	1.6	Jan. 17-19	7.8	17.7
<i>White River.</i>						
Newport, Ark.	24.4	Dec. 19, 20	0.2	Jan. 20-25	4.5	24.2
<i>Yazoo River.</i>						
Yazoo City, Miss.	26.6	Apr. 21, 22	—2.1	Nov. 3, 4	8.0	28.7
<i>Red River.</i>						
Arthur City, Tex.	27.3	June 1	2.5	Oct. 30-Nov. 24	7.5	24.8
Fulton, Ark.	32.2	Dec. 1	2.9	Mar. 2-11	12.5	29.3
Shreveport, La.	34.1	Dec. 15, 16	—1.0	Jan. 24, 25	10.7	35.1
Alexandria, La.	32.4	Dec. 26-29	—2.1	Jan. 25, 26	9.9	34.5
<i>Ouachita River.</i>						
Camden, Ark.	36.2	Dec. 1	4.0	Jan. 21-28	14.2	32.2
Monroe, La.	35.1	Apr. 27, 28	1.3	July 22-29	14.4	33.8
<i>Atchafalaya River.</i>						
Melville, La.	32.9	Apr. 19-22	9.2	Sept. 11, 12	21.5	23.7
<i>Savannah River.</i>						
Binghamton, N. Y. (2)	12.0	July 22	2.7	Oct. 1	4.1	9.3
Towanda, Pa. (2)	24.5	Mar. 2	0.6	Sept. 21-24	3.2	

TABLE VII.—Heights of rivers referred to zeros of gages, 1902—Continued.

Stations.	Highest water.		Lowest water.		Mean stage.	Annual stage.
	Stage.	Date.	Stage.	Date.		
<i>Cape Fear River.</i>	<i>Feet.</i>		<i>Feet.</i>		<i>Feet.</i>	<i>Feet.</i>
Fayetteville, N. C.	41.7	Mar. 2	0.5	Sept. 4, 5, 25	7.4	41.2
<i>Edisto River.</i>						
Edisto, S. C.	5.9	Apr. 21, 22	1.0	July 28, 29	3.6	4.9
<i>Pedee River.</i>						
Cheraw, S. C.	35.5	Jan. 1	1.2	Sept. 25	6.6	34.3
<i>Black River.</i>						
Kingsree, S. C.	10.0	Mar. 5, 6	-0.4	July 28-30 Aug. 4, 5	3.6	10.4
<i>Lynch Creek.</i>						
Effingham, S. C.	15.0	Feb. 8	2.0	Oct. 3-7 July 10, 11, 23-27	5.3	13.0
<i>Santee River.</i>						
St. Stephens, S. C.	15.2	Jan. 7	1.0	Sept. 6	6.5	14.2
<i>Ongaree River.</i>						
Columbia S. C.	22.0	Mar. 2	-0.2	Oct. 26	2.5	22.2
<i>Watauga River.</i>						
Camden, S. C.	30.5	Jan. 1	4.5	Sept. 25, 28	10.1	26.0
<i>Waccamaw River.</i>						
Conway, S. C.	7.2	Mar. 13	0.3	July 20-22	3.1	6.9
<i>Savannah River.</i>						
Calhoun Falls, S. C.	16.4	Feb. 28	1.4	June 11-14	3.3	15.0
Augusta, Ga.	34.6	Mar. 1	6.7	Sept. 4	10.5	27.9
<i>Broad River.</i>						
Carlton, Ga.	24.5	Feb. 28	2.1	Sept. 9-11 Aug. 6-8	3.4	22.4
<i>Flint River.</i>						
Albany, Ga.	22.2	Mar. 7	0.1	Nov. 21	4.9	22.1
<i>Chattahoochee River.</i>						
Westpoint, Ga.	20.0	Mar. 1	1.2	Aug. 26	4.1	18.8
<i>Ocmulgee River.</i>						
Macon, Ga.	22.8	Mar. 1	3.1	(7)	5.6	19.7

<sup>1</sup> Frozen for 3 months.<sup>2</sup> Frozen for 1 month.<sup>3</sup> Frozen for 2 months.<sup>4</sup> 10 months only.<sup>5</sup> 9 months only.<sup>6</sup> 11 months only.

TABLE VII.—Heights of rivers referred to zeros of gages, 1902—Continued.

Stations.	Highest water.		Lowest water.		Mean stage.	Annual stage.
	Stage.	Date.	Stage.	Date.		
<i>Oconee River.</i>	<i>Feet.</i>		<i>Feet.</i>			
Dublin, Ga.	25.8	Mar. 5	-1.3	Sept. 11	4.3	27.1
<i>Coosa River.</i>						
Rome, Ga.	28.9	Mar. 30	0.2	Oct. 27, Nov. 1-5	3.7	28.6
<i>Gadsden, Ala.</i>						
Gadsden, Ala.	22.7	Mar. 6	-0.9	Nov. 13-17	4.0	23.6
<i>Alabama River.</i>						
Montgomery, Ala.	47.8	Mar. 31	-0.2	Sept. 24	8.4	48.0
<i>Selma, Ala.</i>						
Selma, Ala.	50.7	Apr. 2	-0.4	Aug. 25-27	10.4	51.1
<i>Tombigbee River.</i>						
Columbus, Miss.	30.6	Mar. 31	-3.6	Aug. 25-27	1.8	34.2
<i>Demopolis, Ala.</i>						
Demopolis, Ala.	64.5	Apr. 3	-3.1	Aug. 27	12.7	67.6
<i>Black Warrior River.</i>						
Tuscaloosa, Ala.	60.6	Mar. 29	0.0	(8)	10.7	60.6
<i>Brazos River.</i>						
Kopperl, Tex.	21.0	July 26, 28	-2.0	Aug. 20-Sept. 2	0.4	23.0
<i>Waco, Tex.</i>						
Waco, Tex.	33.3	July 27	0.2	Apr. 30	4.1	33.1
<i>Booth, Tex.</i>						
Booth, Tex.	38.0	Aug. 8	-0.7	Jan. 19-24	5.9	38.7
<i>Red River of the North.</i>						
Moorhead, Minn. (1)	10.5	May 23	6.7	Nov. 13, 14	7.5	3.8
<i>Columbia River.</i>						
Umatilla, Oreg.	21.7	May 31	-0.2	Feb. 10	6.9	21.9
<i>The Dalles, Oreg.</i>						
The Dalles, Oreg.	36.8	June 1	-0.8	Feb. 4	10.7	37.6
<i>Willamette River.</i>						
Albany, Oreg.	24.5	Dec. 6	0.8	(Sept. 1-20) (Oct. 4-12)	5.3	23.7
<i>Portland, Oreg.</i>						
Portland, Oreg.	20.8	June 4	0.3	Feb. 2	8.1	20.5
<i>Sacramento River.</i>						
Red Bluff, Cal.	24.7	Feb. 10, 24	-0.1	(Sept. 28-Oct. 11) (Oct. 15-20)	4.2	24.8
<i>Sacramento, Cal.</i>						
Sacramento, Cal.	28.2	Mar. 1	6.9	Oct. 6-8	14.8	21.3

<sup>7</sup> On various dates.<sup>8</sup> On various dates in July and August.<sup>9</sup> Data incomplete.

TABLE VIII.—Average monthly and annual departures of temperature from the normal, during 1902.

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England	-1.0	0.0	+7.4	+2.4	-0.4	-2.3	-2.1	-1.6	+0.3	+1.1	+4.2	-3.5	+0.4
Middle Atlantic	-2.0	-5.3	+5.3	+0.8	+0.4	-1.9	+0.2	-1.3	-0.5	+1.9	+6.3	-2.0	+0.2
South Atlantic	-3.7	-7.9	+0.9	-1.6	+2.6	+0.4	-1.6	-0.1	-0.8	+2.6	+5.8	+0.2	+0.1
Florida Peninsula	-2.4	-5.8	+0.5	-0.6	+2.3	+1.0	+0.8	+0.6	+0.8	+2.6	+3.5	+1.3	+0.4
East Gulf	-1.5	-8.5	+0.6	-1.2	+4.0	+2.5	+1.4	+3.2	-0.1	+0.4	+5.4	-1.7	+0.4
West Gulf	-0.2	-4.9	+1.9	+0.6	+3.4	+2.1	-0.5	+2.9	-1.2	+1.3	+6.4	-1.8	+0.8
Ohio Valley and Tennessee	-0.7	-0.8	+2.7	+1.7	+3.9	+1.3	+0.9	0.0	-1.3	+2.5	+8.6	-2.5	+0.1
Lower Lakes	-0.4	-4.7	+7.0	+1.6	-0.2	-4.1	-0.4	-2.2	-0.1	+0.9	+8.4	-3.0	+0.3
Upper Lakes	+3.3	+0.9	+8.2	+1.7	+1.6	-4.0	+1.4	-1.7	-1.8	+1.6	+8.0	-1.1	+1.5
North Dakota	+8.7	+4.4	+7.0	-1.4	+3.5	-5.4	-0.2	-1.1	-3.1	+0.2	+5.3	-5.4	+1.0
Upper Mississippi Valley	+4.3	-5.5	+5.5	-1.1	+4.4	-3.3	+0.2	-1.8	-3.6	+3.3	+8.3	-3.4	+0.6
Missouri Valley	+5.9	-3.2	+3.1	-0.8	+5.3	-3.6	-0.4	-0.8	-4.2	+3.2	+5.2	-6.5	+0.4
Northern Slope	+5.8	+4.8	+1.8	-0.6	+3.1	-2.1	-2.4	+0.3	-1.4	+3.4	+0.9	-3.9	+0.8
Middle Slope	+1.8	-0.2	+2.4	+0.5	+4.1	-0.4	-0.9	+3.0	-4.0	+2.9	+3.8	-4.0	+0.8
Southern Slope	+1.2	+0.3	+1.5	+1.0	+1.7	+1.9	-1.0	+4.0	-3.2	+3.2	+3.6	-1.6	+1.0
Southern Plateau	+2.2	+1.6	-4.0	+2.3	-1.5	+1.1	-3.3	-1.2	+0.5	+1.6	-0.4	-0.4	-0.1
Middle Plateau	+1.6	+6.7	-2.5	-0.1	-0.8	+1.6	-3.7	-1.5	-0.6	+1.1	-0.9	+1.0	-0.2
Northern Plateau	+1.8	+6.1	+0.9	-1.3	-0.7	-0.3	-3.3	-1.7	+0.5	+3.4	0.0	-0.3	+0.4
North Pacific	+0.6	+4.6	-1.3	-1.1	-0.3	-0.1	-0.7	+0.2	-0.1	+2.1	+0.2	-0.3	+0.3
Middle Pacific	-1.2	+2.4	-1.9	-0.4	-1.5	+0.5	+0.1	+0.3	+1.4	+0.9	-1.0	+0.2	0.0
South Pacific	+1.6	+0.6	-1.9	-1.0	-1.5	+0.8	-1.1	-2.0	+0.8	-0.5	-1.6	+0.1	-0.5

TABLE IX.—Monthly and annual departures of precipitation from the normal, during 1902.

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England.....	-1.8	+0.5	+2.3	-0.1	-1.7	+1.0	-1.1	-1.4	+0.3	+0.6	-2.9	+2.2	-2.1
Middle Atlantic.....	-1.0	+1.3	-0.4	-0.8	-1.6	+0.9	-1.1	-1.2	+1.0	+2.0	-0.5	+1.6	+0.2
South Atlantic.....	-2.7	+0.8	-0.8	-1.3	-1.6	-1.8	-1.6	-2.1	-0.8	+0.2	+1.3	+0.2	+0.2
Florida Peninsula.....	-2.3	+1.9	+0.7	-1.0	-0.9	+0.5	-0.3	-1.4	+0.7	+2.4	+1.0	+0.3	+1.6
East Gulf.....	-2.9	+1.5	+1.7	-1.7	-1.4	-4.2	-3.0	-2.6	+2.0	+0.9	-0.3	+0.7	-9.3
West Gulf.....	-1.1	-1.7	-0.2	-1.7	-1.4	-0.2	+1.7	-3.1	+1.0	-0.3	+1.9	-0.5	-5.6
Ohio Valley and Tennessee.....	-1.0	-2.6	-0.3	-1.8	-0.3	+1.0	-1.6	-1.4	+0.9	-0.5	-0.4	+1.5	-6.5
Lower Lakes.....	-0.9	-1.5	-0.3	-0.6	-0.2	+2.5	+2.3	-1.6	+1.4	-0.7	-1.6	+0.2	-1.0
Upper Lakes.....	-1.3	+0.8	-0.1	-0.5	+0.5	+0.3	+1.1	-1.1	-0.2	-0.7	0.0	-0.1	-2.9
North Dakota.....	-0.4	+0.3	+1.5	-0.9	+1.4	-0.4	-0.4	+0.3	-0.6	+0.4	-0.4	-0.1	+0.7
Upper Mississippi Valley.....	-0.8	-1.0	+0.3	-0.7	+0.3	+1.2	+0.6	+2.0	-0.1	-0.3	+0.1	+0.7	+2.3
Missouri Valley.....	-0.2	-0.6	0.0	-1.4	-1.1	+1.0	+1.6	+1.1	+0.7	-0.2	+0.2	+1.1	+2.2
Northern Slope.....	-0.5	-0.2	+0.5	-0.6	+1.4	-0.4	+0.3	-0.4	+0.4	-0.3	-0.1	+0.2	+0.3
Middle Slope.....	-0.5	-0.5	+0.5	-1.1	+2.8	-0.4	-0.2	-0.6	+0.7	+0.2	+1.0	-0.2	+3.7
Southern Slope.....	-0.8	-0.9	+1.2	-0.3	+4.8	-2.6	+0.6	-0.9	+2.1	-0.4	+2.2	-0.2	+4.8
Southern Plateau.....	-0.5	-0.4	0.0	-0.3	+0.1	-0.3	-0.4	+0.2	+0.2	-0.5	+1.1	-0.2	-1.0
Middle Plateau.....	-0.6	+0.2	+0.1	+0.2	-0.6	-0.4	+0.1	-0.4	-0.2	-0.6	+0.2	-0.3	-2.3
Northern Plateau.....	-1.2	-0.8	0.6	+0.2	+0.6	-0.8	+0.8	-0.1	-0.7	-0.7	+0.7	+0.2	-0.8
North Pacific.....	-2.7	+6.0	+1.0	-0.8	-0.2	-0.6	+0.7	-0.4	-1.0	-2.0	+3.5	+2.3	+5.8
Middle Pacific.....	-3.9	+6.4	-0.3	-0.1	-0.2	-0.4	0.0	-0.1	-0.7	+0.8	+1.6	-1.5	+1.6
South Pacific.....	-1.4	+1.4	+0.4	-0.5	-0.4	-0.1	+0.2	0.0	-0.1	+0.1	+0.5	-1.0	-0.9

TABLE X.—Monthly and annual departures of relative humidity from the normal, during 1902.

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England.....	-2	0	+5	+5	-6	-3	+1	-2	+2	-2	+3	+2	+0.2
Middle Atlantic.....	-2	0	+5	+1	-2	-3	+3	0	+2	+3	+4	+3	+1.0
South Atlantic.....	-5	-6	+1	-9	0	-3	-5	-3	0	0	+4	-1	-1.5
Florida Peninsula.....	0	-3	0	-2	-4	-2	-3	-5	-1	0	+0	-3	-1.9
East Gulf.....	-5	-7	0	-12	0	-10	-7	-5	+2	+2	+2	0	-2.5
West Gulf.....	0	0	-2	+2	+4	-5	+3	-1	+3	+4	+9	+4	+1.8
Ohio Valley and Tennessee.....	-2	+3	-1	+2	0	+2	+1	+2	+3	+5	+5	+4	+1.8
Lower Lakes.....	-2	+2	0	0	0	+2	+8	+4	+3	+4	+1	+4	+2.1
Upper Lakes.....	-2	+1	-1	-3	+1	+1	+5	+1	+5	-1	0	+1	+0.5
North Dakota.....	-3	-2	+3	+4	+10	+5	0	+8	-2	+2	-2	0	+1.9
Upper Mississippi Valley.....	-2	+3	+3	-2	+5	+1	+5	+6	+4	+3	+6	+6	+3.2
Missouri Valley.....	-4	+3	-3	-4	+4	+3	+3	+8	-2	+3	+5	+7	+1.9
Northern Slope.....	+6	+9	+2	+6	+8	+7	+6	+7	+5	+7	+6	+13	+6.8
Middle Slope.....	+1	+4	0	+3	+8	+6	+2	0	+5	+7	+12	+10	+4.8
Southern Slope.....	-8	-14	-9	+3	+7	-2	+9	-9	0	0	+17	+5	-0.1
Southern Plateau.....	-8	-8	+2	-4	+1	-4	-5	-7	-5	-8	+4	+4	-3.2
Middle Plateau.....	0	0	+5	-3	-3	-5	+1	+5	+1	-2	+8	+1	+0.7
Northern Plateau.....	+1	+1	-4	-12	+3	0	+4	+1	-5	-2	+3	+1	0.0
North Pacific.....	-1	-2	-2	-12	-12	-9	-7	-5	-6	-3	+1	0	-3.2
Middle Pacific.....	-6	+10	-4	+1	-1	-6	-7	-1	-3	+1	+6	-2	-1.0
South Pacific.....	-8	+8	-4	0	0	+1	+3	+6	+5	+5	+5	-2	+1.6

TABLE XI.—Monthly and annual departures of average cloudiness from the normal, during 1902.

Districts.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New England.....	-0.2	+0.1	+0.7	+0.6	-0.1	+0.2	+0.9	-0.2	+0.8	+0.1	+0.9	+0.1	+0.3
Middle Atlantic.....	+0.5	+0.1	+0.1	+0.7	-0.1	0.0	+0.6	-0.4	+0.4	-0.2	+0.8	+0.8	+0.3
South Atlantic.....	-0.6	-0.1	+0.2	-0.3	-0.5	-0.8	-0.7	-0.5	+0.2	+0.2	+0.9	+0.5	-0.1
Florida Peninsula.....	-0.5	+0.3	+0.1	-0.4	-0.2	-0.1	+0.1	-0.5	-0.4	+0.7	+0.5	-0.9	-0.1
East Gulf.....	-0.1	+0.8	+0.9	0.0	+0.4	-1.6	+0.4	+0.1	+1.7	+0.8	+1.1	+0.6	+0.4
West Gulf.....	+0.1	0.0	-0.5	-0.2	+0.3	-1.4	+0.9	-1.9	0.0	-0.3	+1.7	+0.4	-0.1
Ohio Valley and Tennessee.....	-0.5	+0.1	+0.2	-0.1	-0.3	+0.2	-0.3	+0.2	+1.0	0.0	+0.8	+1.4	+0.2
Lower Lakes.....	-0.3	0.0	-0.1	+0.9	-0.3	+0.8	-0.7	+0.3	+0.6	+0.4	-0.5	+0.5	+0.1
Upper Lakes.....	-0.3	-0.4	0.0	+0.3	+0.4	+0.8	+0.9	0.0	+1.2	-0.1	+0.6	+0.6	+0.3
North Dakota.....	-0.9	+0.7	+0.8	-0.7	-0.3	+0.2	-0.7	+0.5	-0.3	-0.4	+0.7	-0.4	-0.1
Upper Mississippi Valley.....	-0.8	-0.2	+0.9	-0.9	+0.3	+1.0	+0.5	+1.4	+1.1	0.0	+1.5	+1.1	+0.5
Missouri Valley.....	-0.9	+0.4	0.0	-0.7	-0.2	+0.7	-0.2	+1.3	+0.2	-0.2	+1.0	+1.3	+0.2
Northern Slope.....	-0.4	+1.2	+0.3	-0.3	-0.2	+0.3	+0.2	+3.0	+0.1	-0.3	+0.6	+1.0	+0.5
Middle Slope.....	+0.1	+0.9	+0.3	+0.3	+0.6	+1.2	+0.2	+0.2	+0.6	+0.5	+2.2	+1.0	+0.7
Southern Slope.....	+0.8	0.0	0.0	+0.4	+0.1	-0.8	+2.2	-2.0	+0.4	-0.2	+2.4	+0.2	+0.3
Southern Plateau.....	+0.6	+0.1	+0.3	-0.1	+0.4	-0.7	-0.7	-0.1	+0.2	0.0	+0.9	+0.5	+0.1
Middle Plateau.....	+0.2	+1.5	+0.5	+0.5	+0.1	-0.6	+0.9	+1.1	0.0	-0.2	+1.3	-0.3	+0.4
Northern Plateau.....	-0.7	+1.4	+0.3	+0.1	+0.7	-0.5	+0.2	-0.3	-0.5	-0.8	+0.6	+0.5	+0.1
North Pacific.....	-1.1	+1.3	+1.0	+0.9	+1.3	-0.5	+0.2	-0.3	-0.6	+0.2	+1.6	+1.1	+0.7
Middle Pacific.....	+0.3	+3.1	-0.7	+0.8	+0.1	-1.5	-0.4	+0.8	+0.4	+1.3	+1.5	+0.4	+0.5
South Pacific.....	+0.6	+1.3	-0.5	+0.1	-0.6	-0.8	+0.5	+0.6	+0.4	+0.6	+0.6	0.0	+0.2



Chart I. Sea-Level Pressure and Temperature; Resultant Surface Winds. 1902.

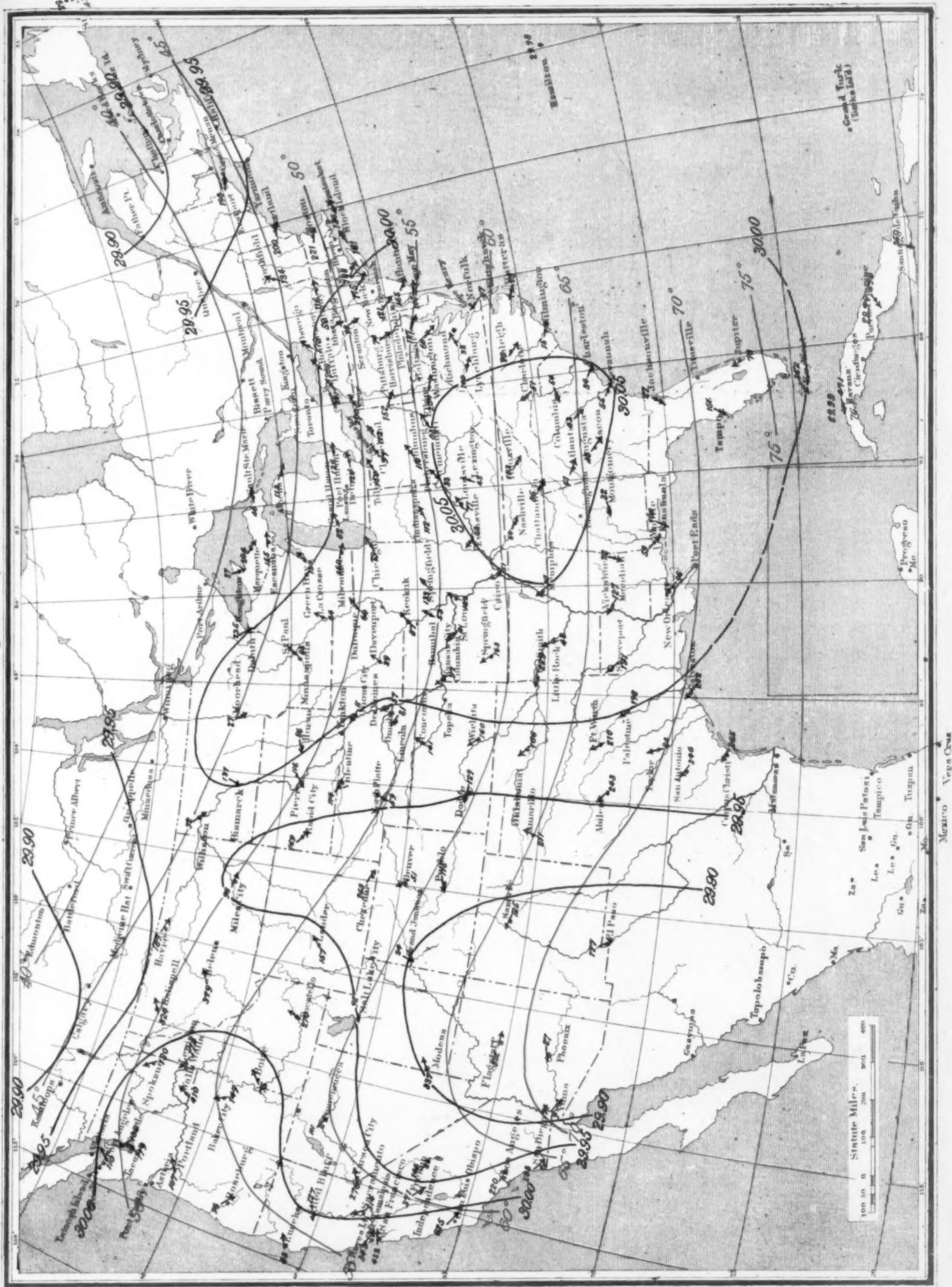




Chart III. Surface Temperatures, 1902.

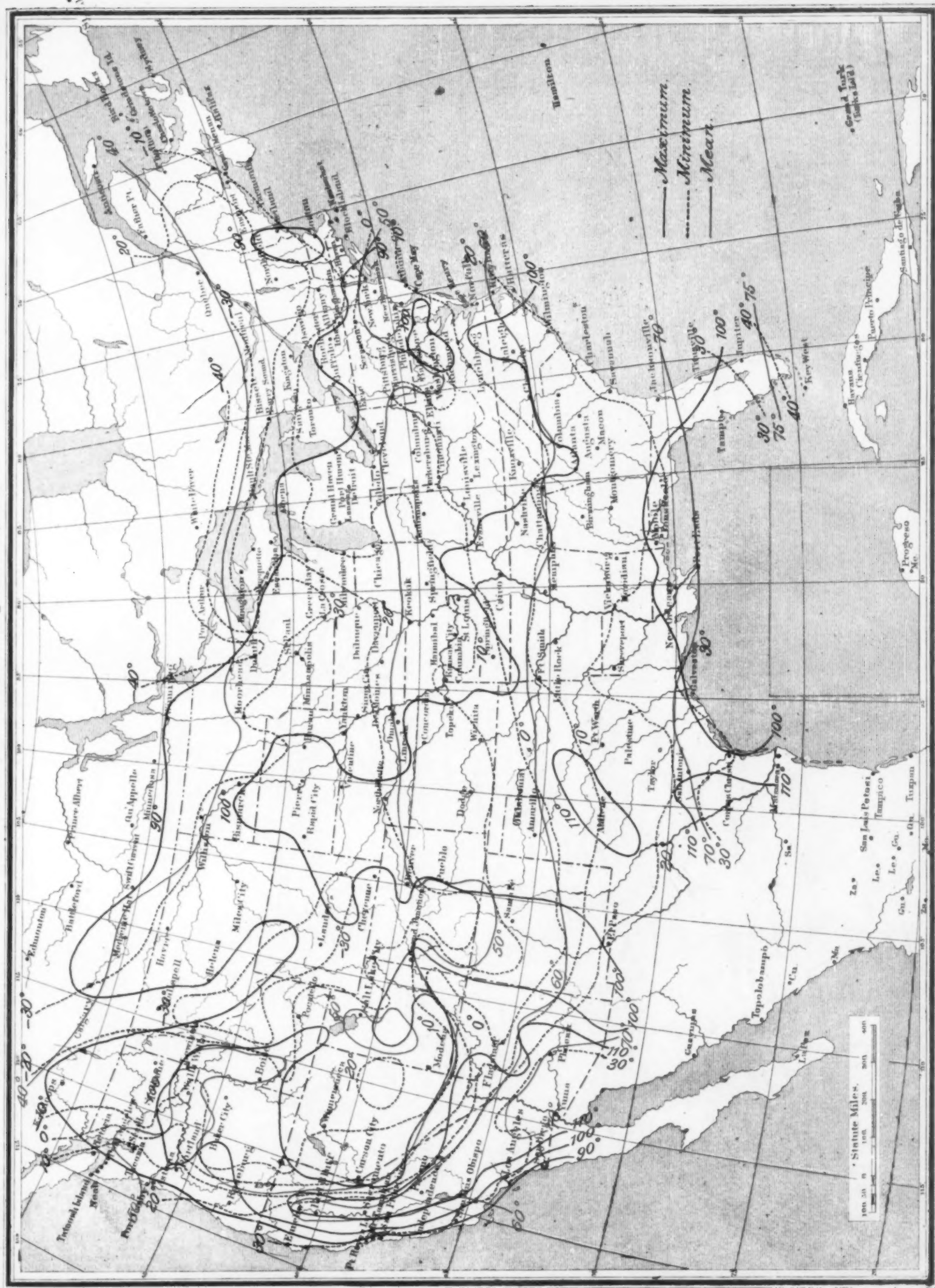


Chart IV. Total Annual Precipitation, 1902.

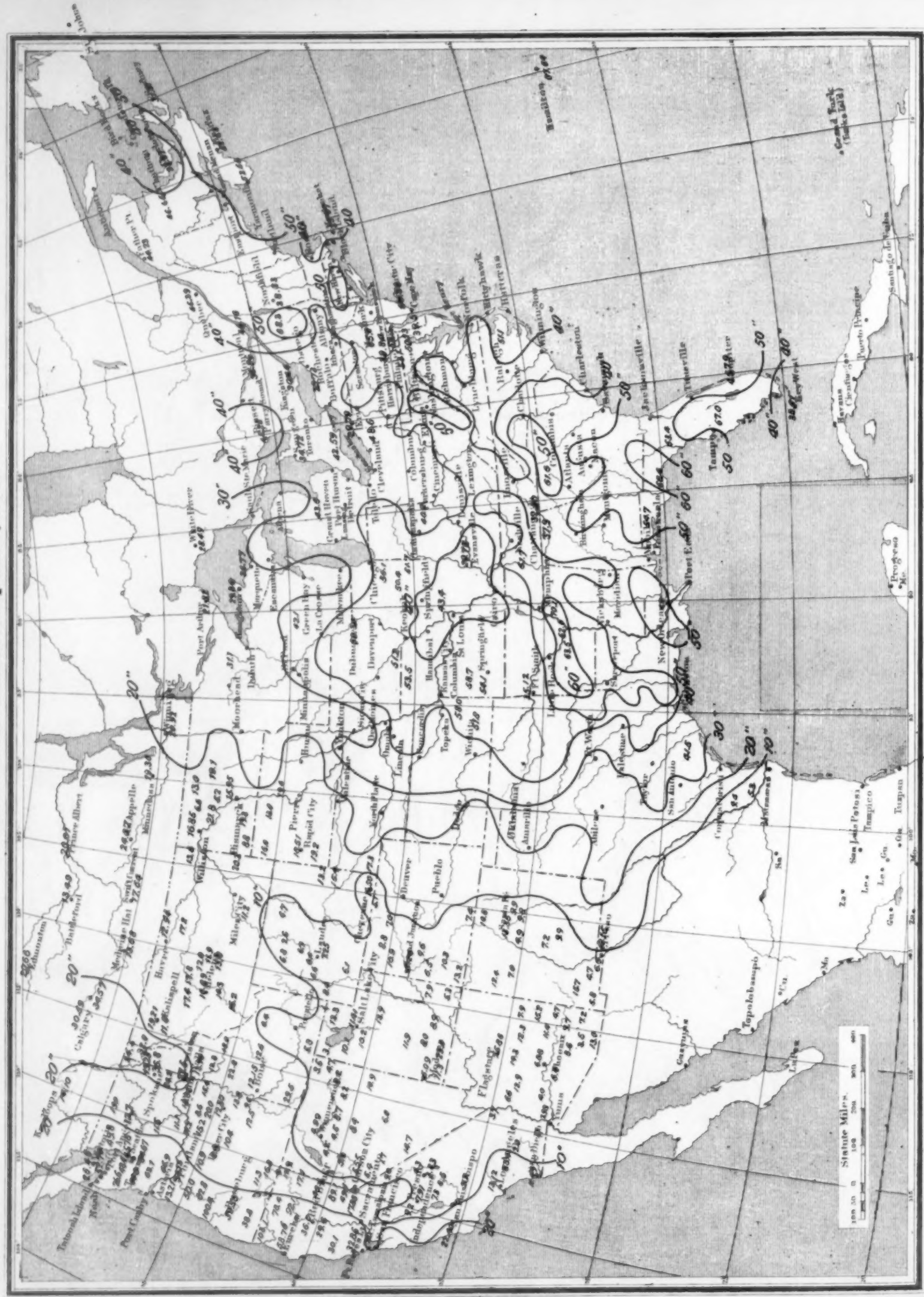


Chart V. Total Number of Thunderstorm Days, 1902.

Chart V. Total Number of Thunderstorm Days, 1902.

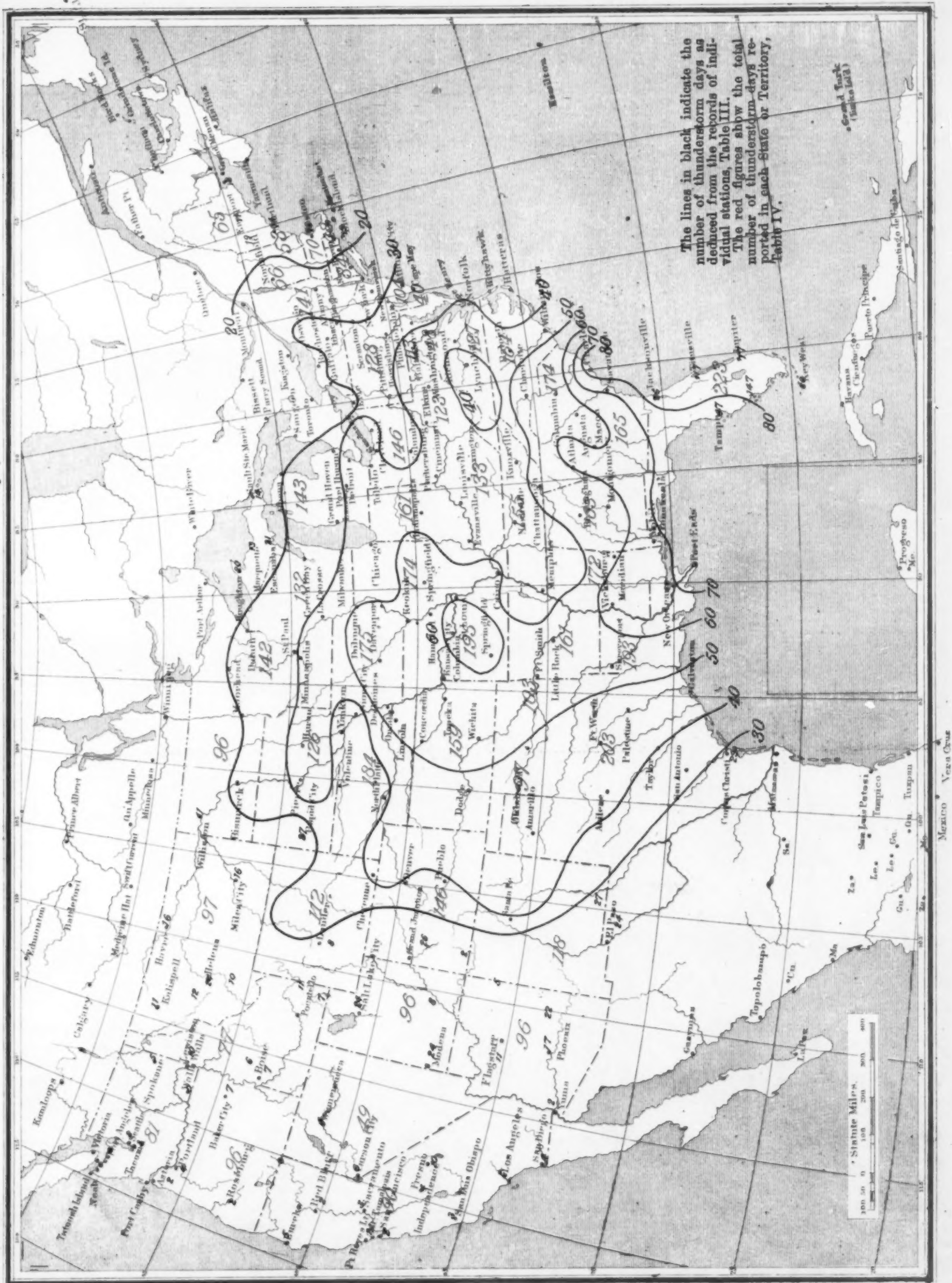


Chart VI. Percentage of Sunshine, 1902.

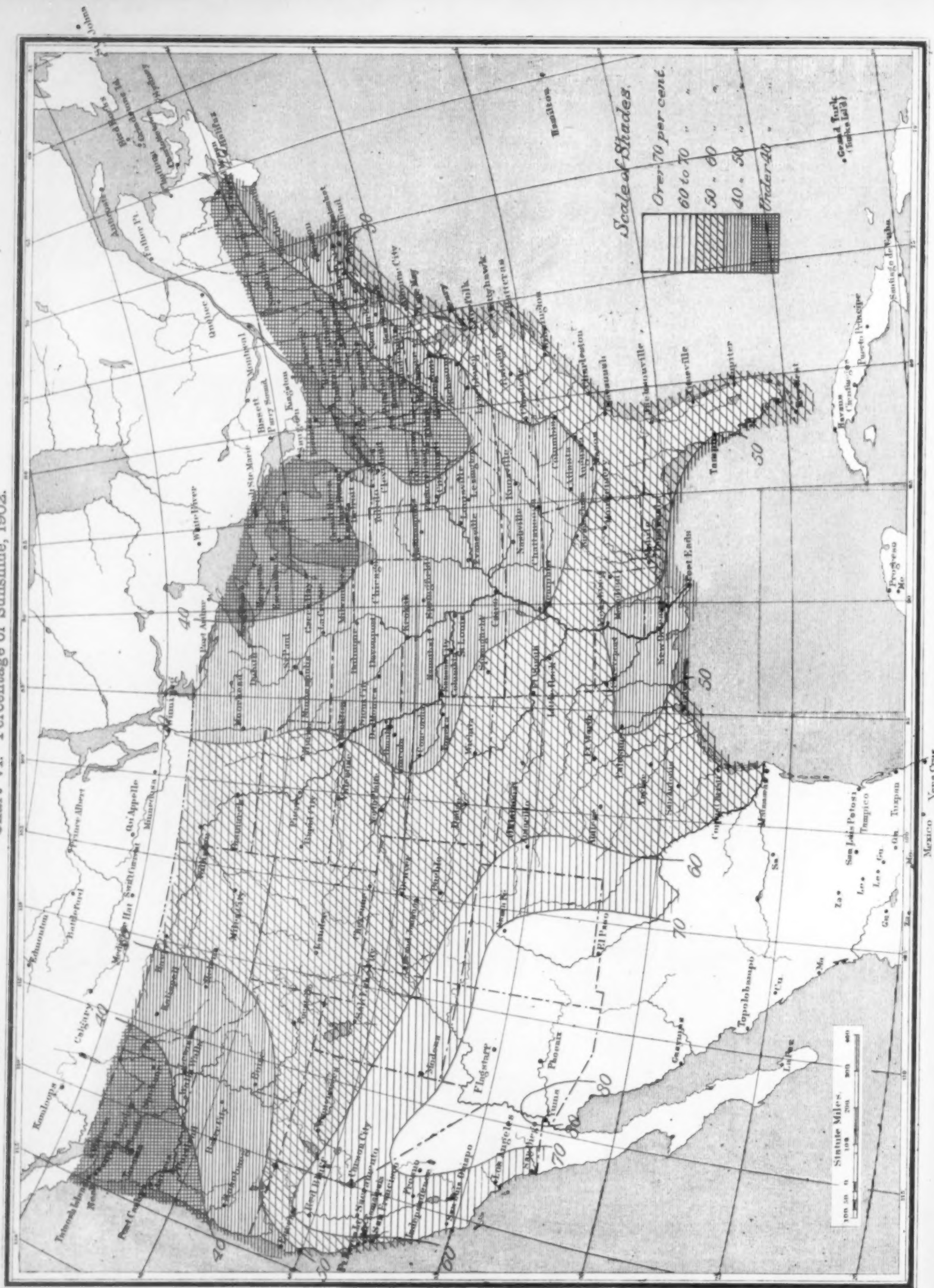
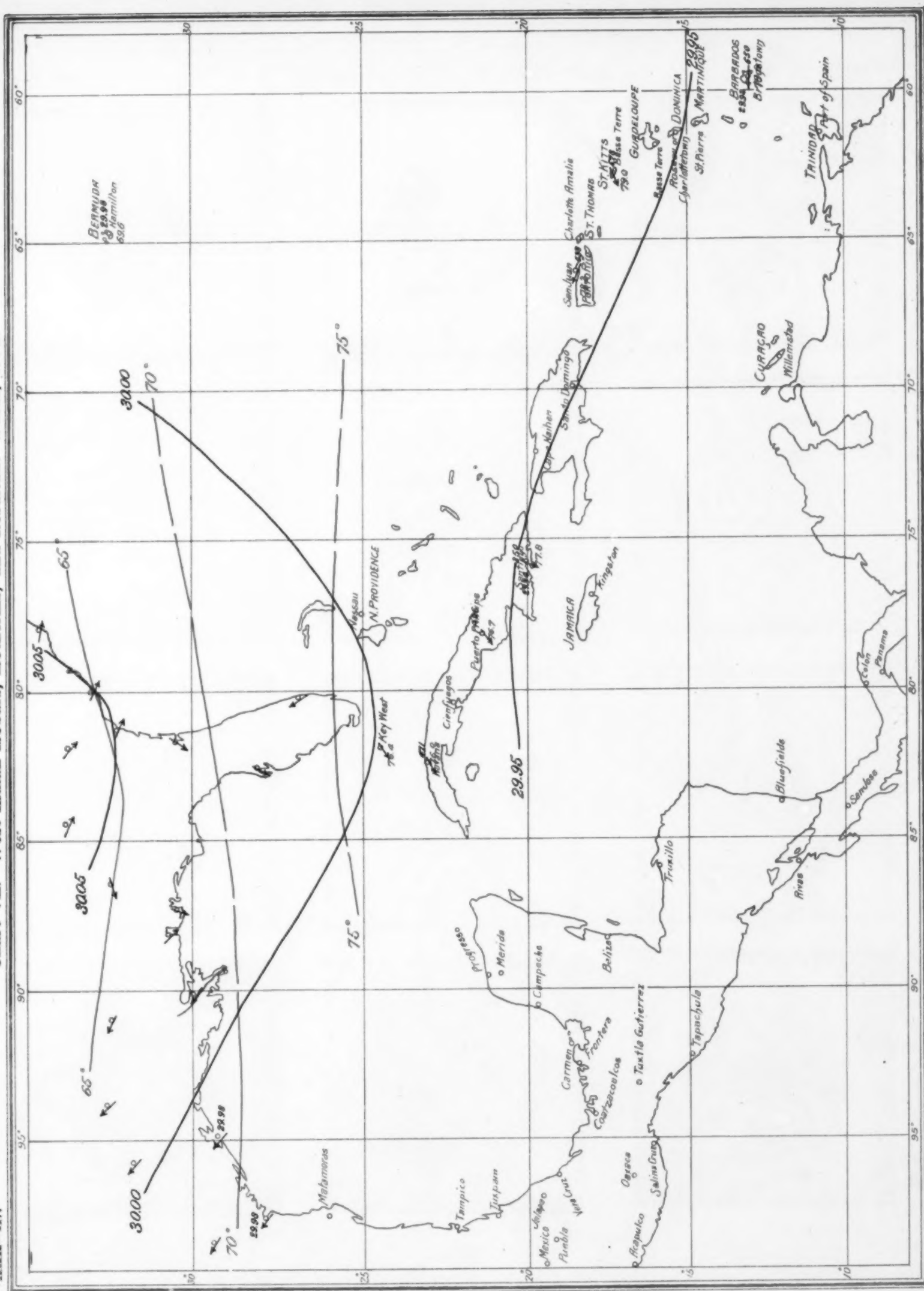
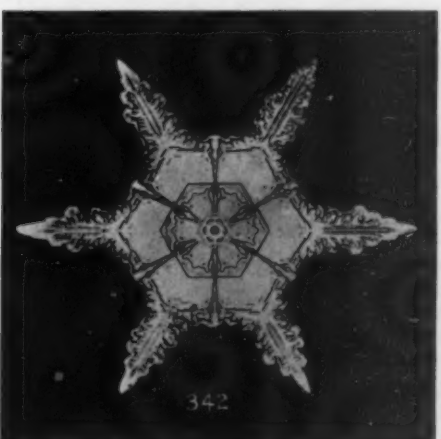
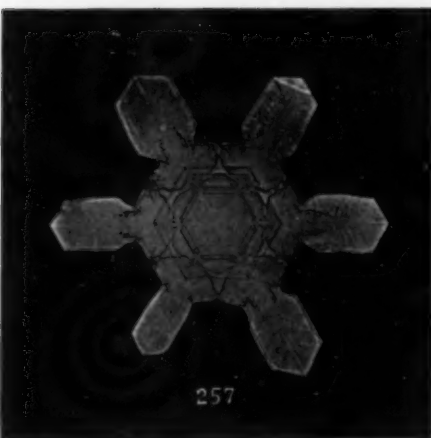
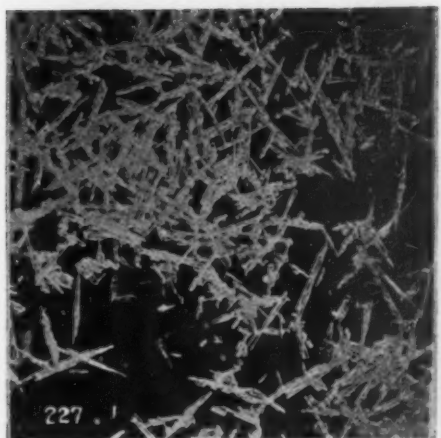
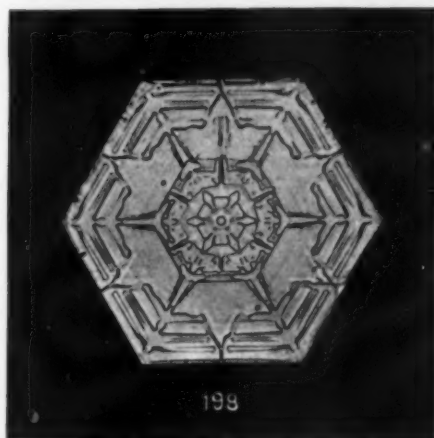
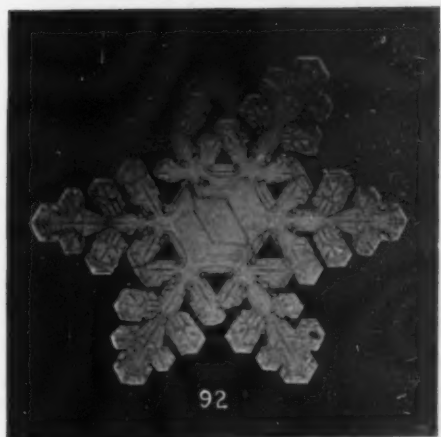
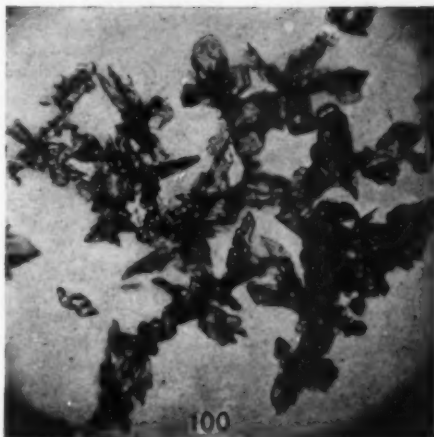
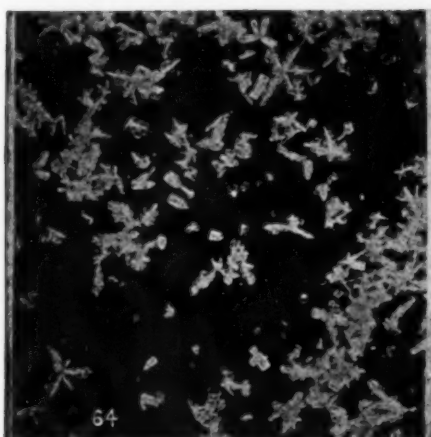
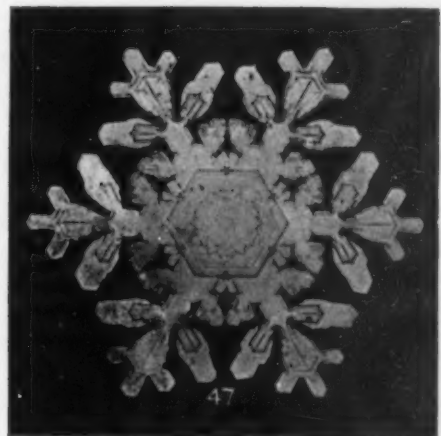
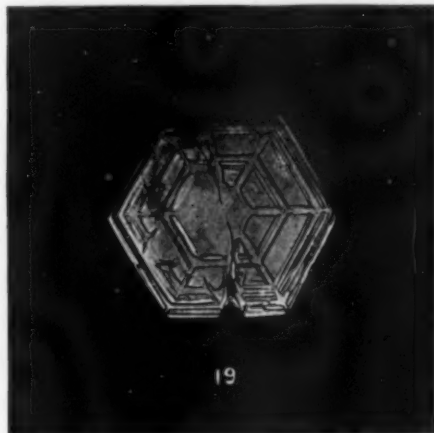
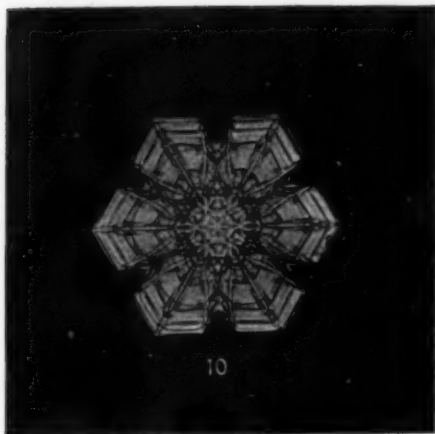


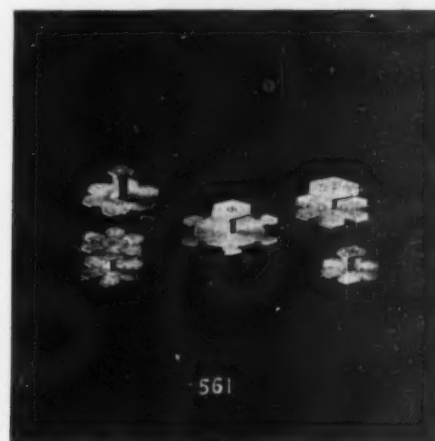
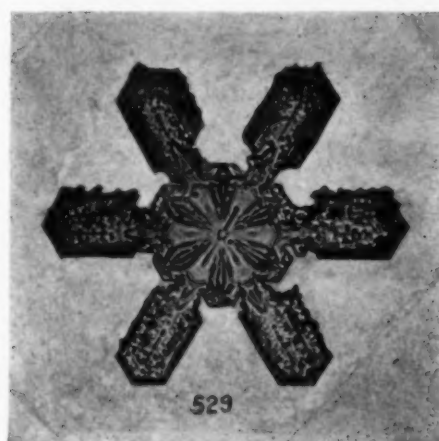
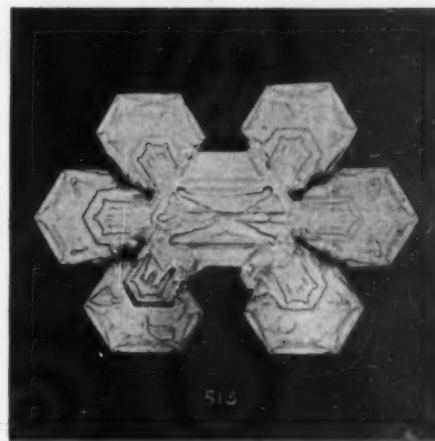
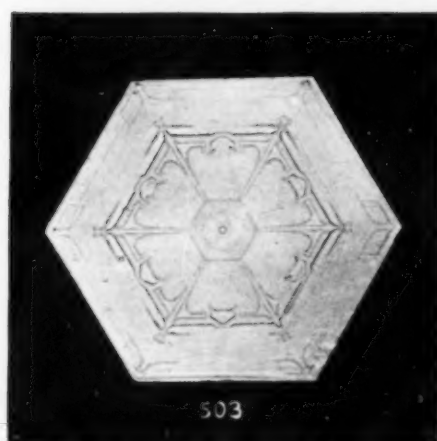
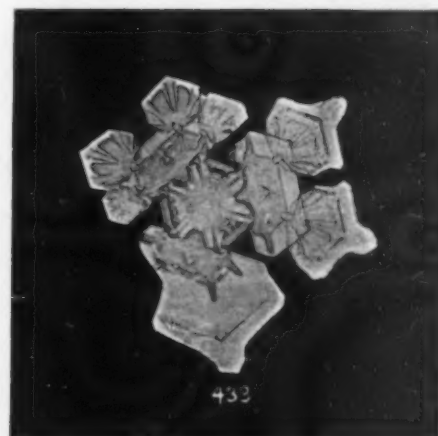
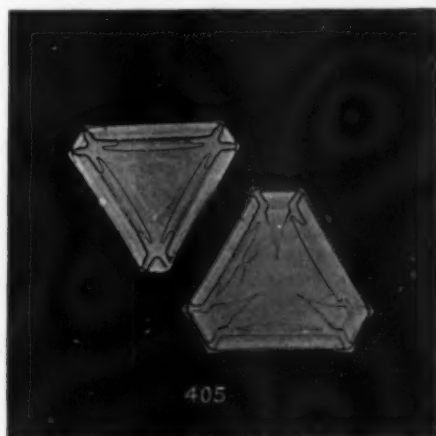
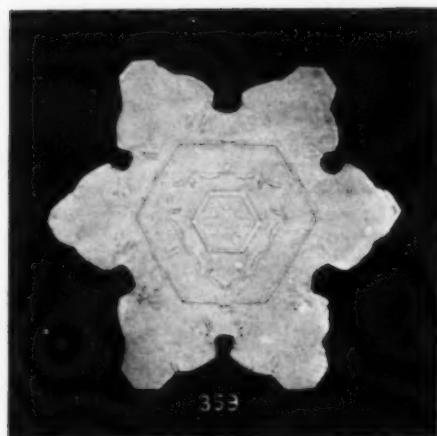
Chart VII. West Indian Isobars, Isotherms, and Resultant Winds, 1902.



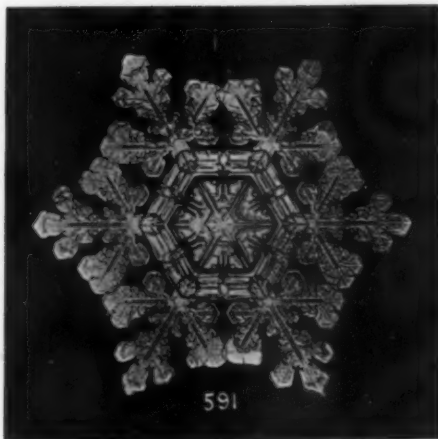
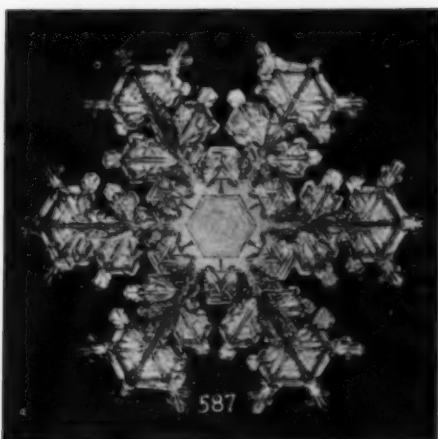
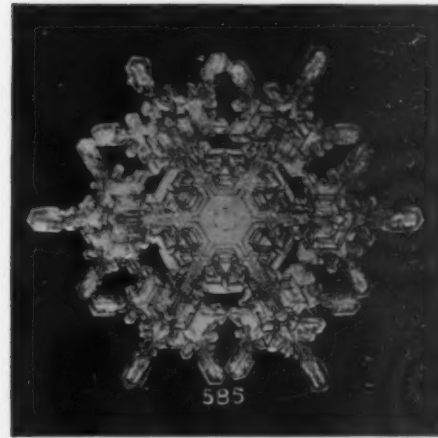
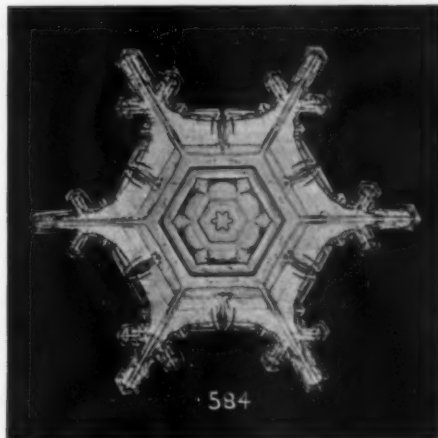
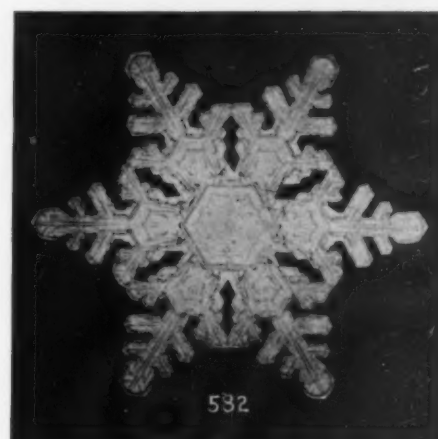
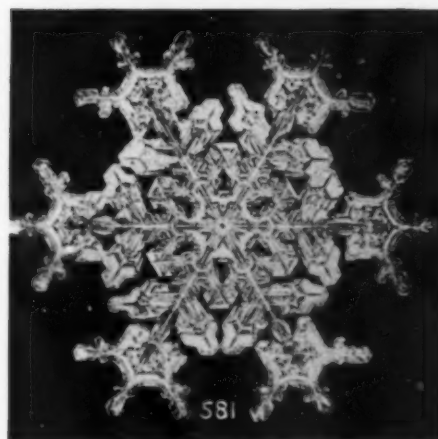
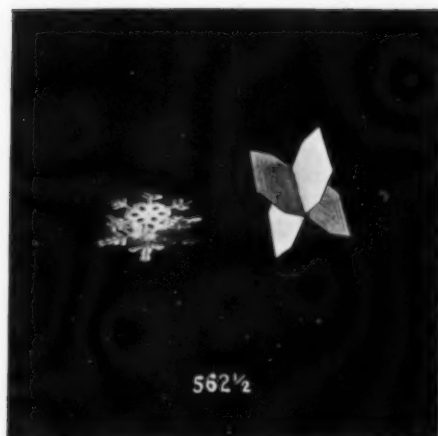




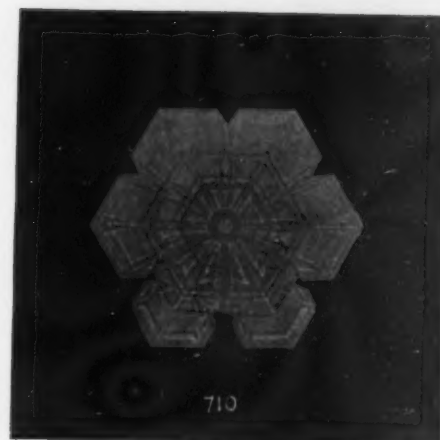
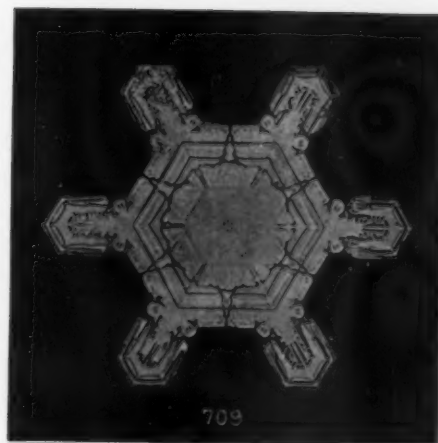
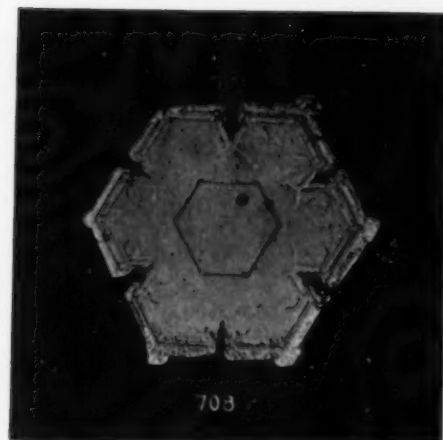
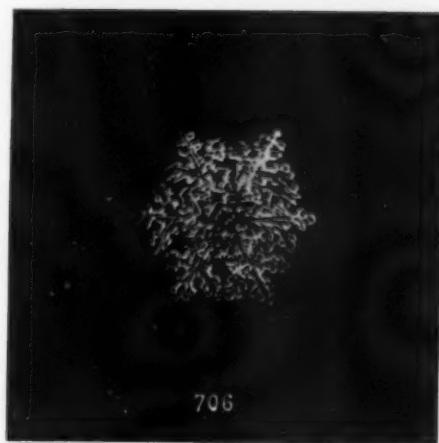
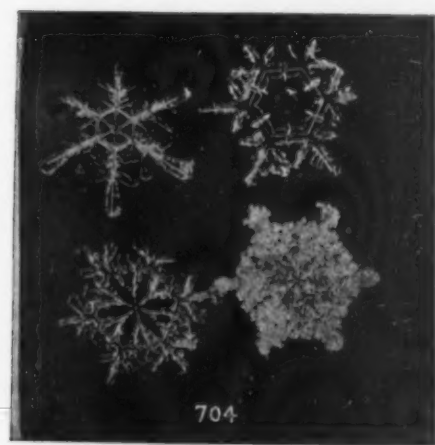
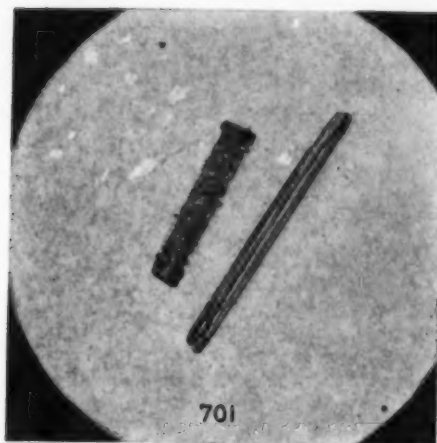
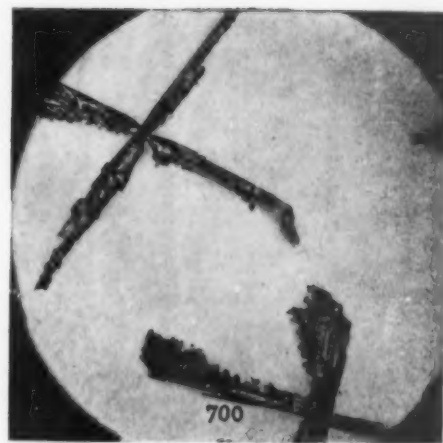
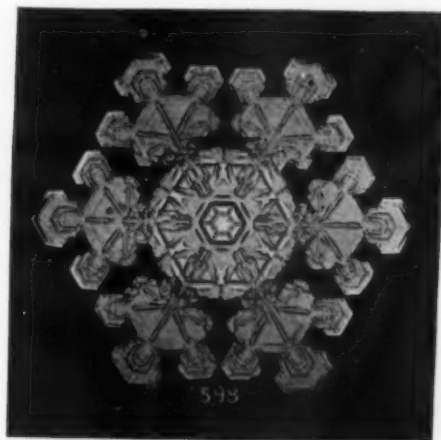
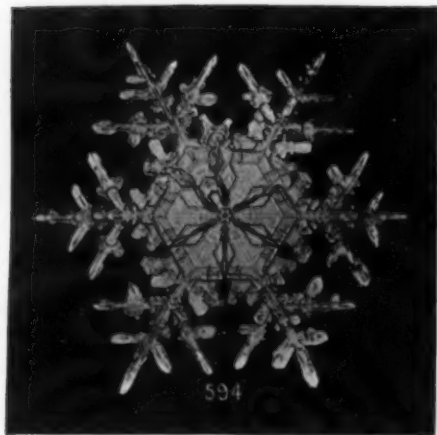




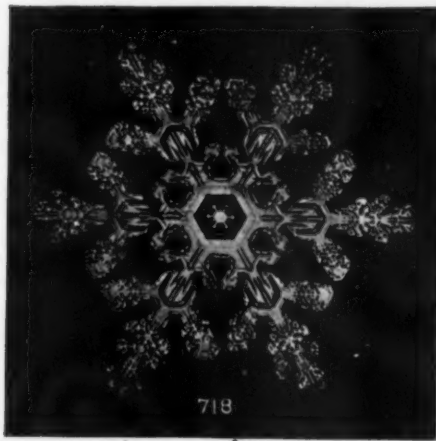
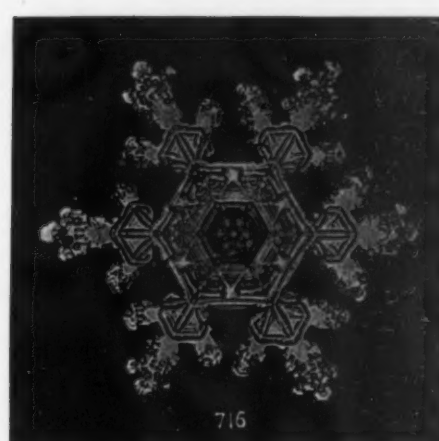
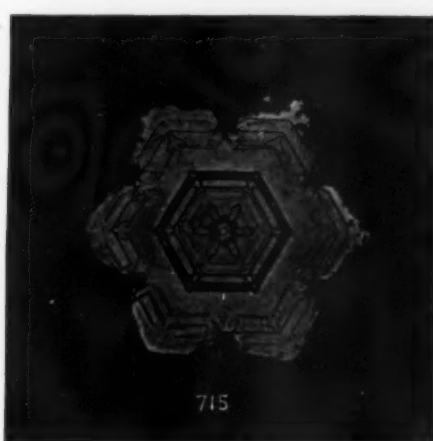
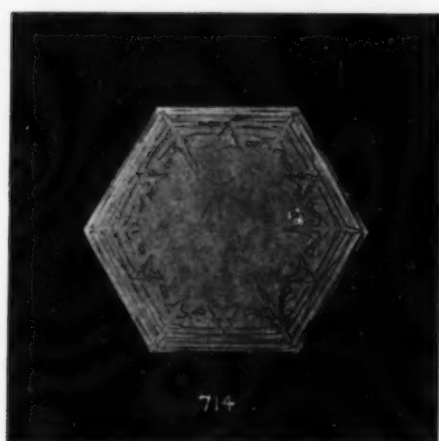
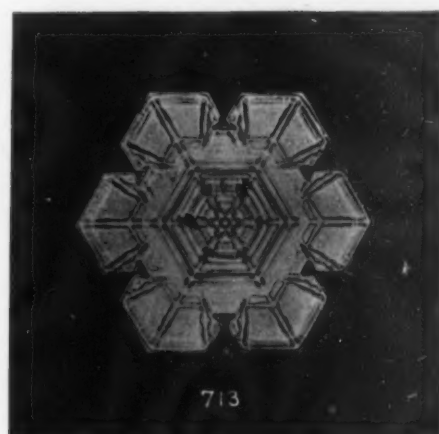




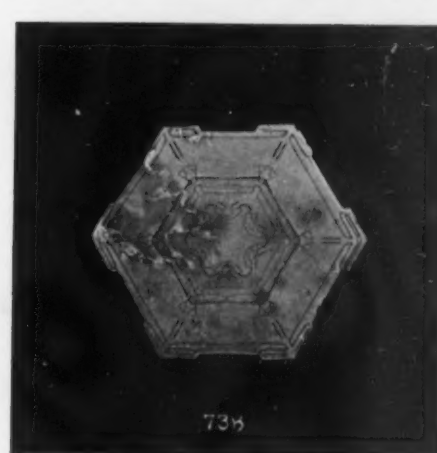
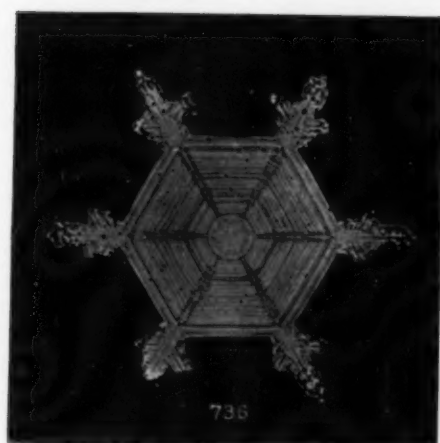
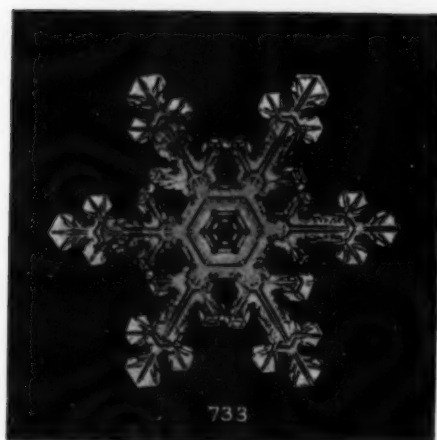
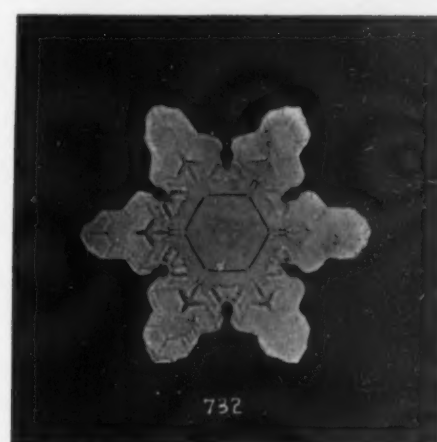
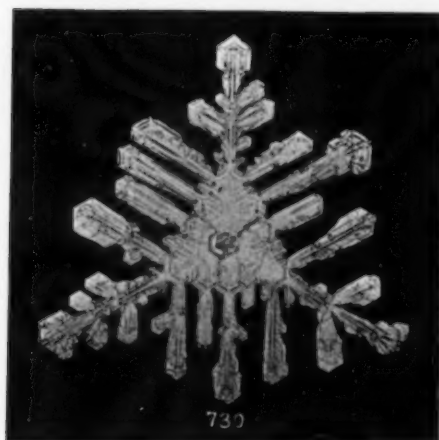
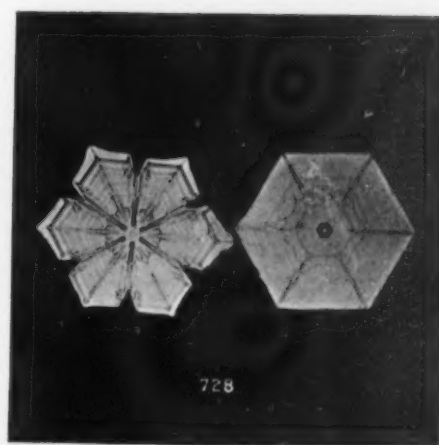
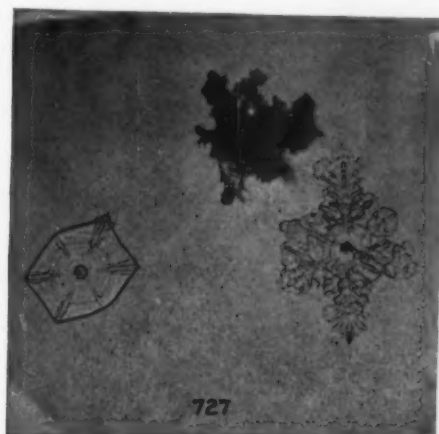




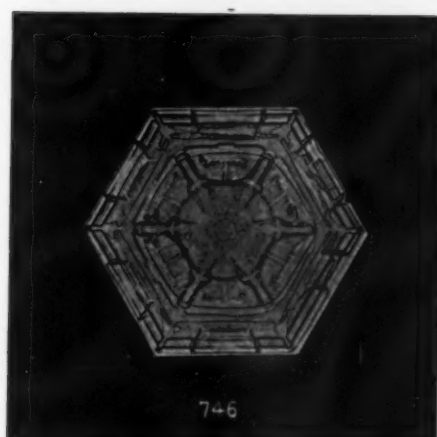
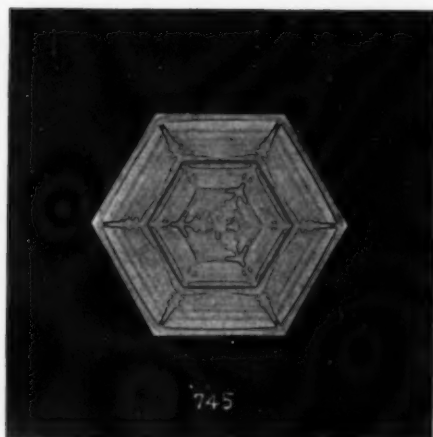
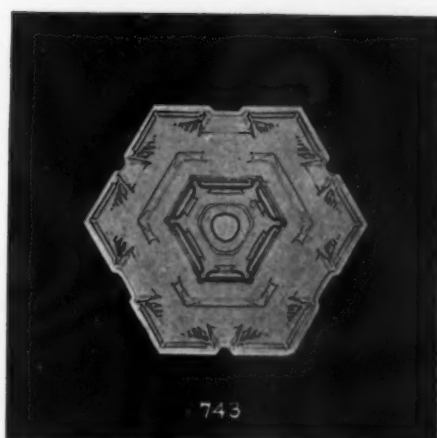
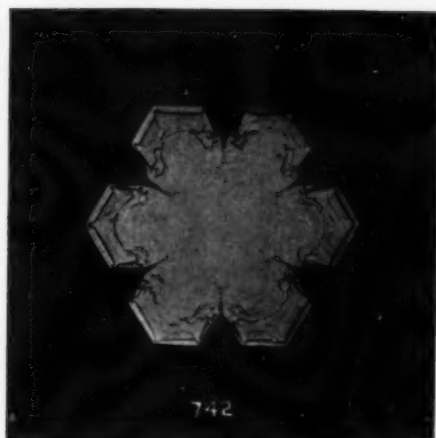
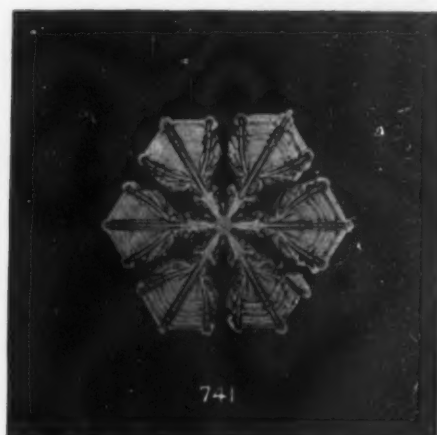
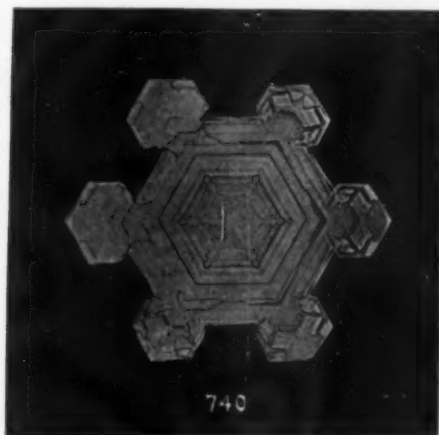
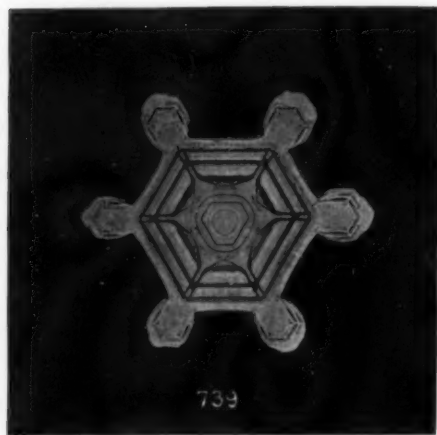




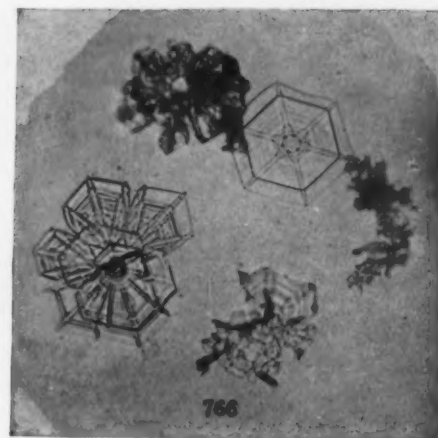
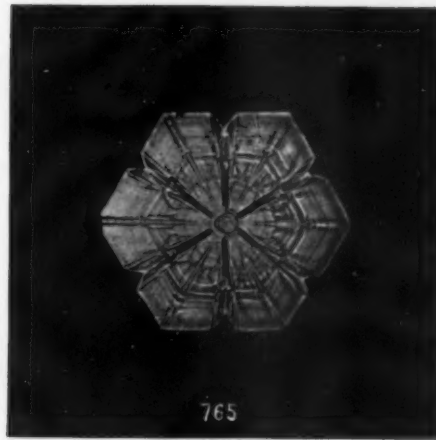
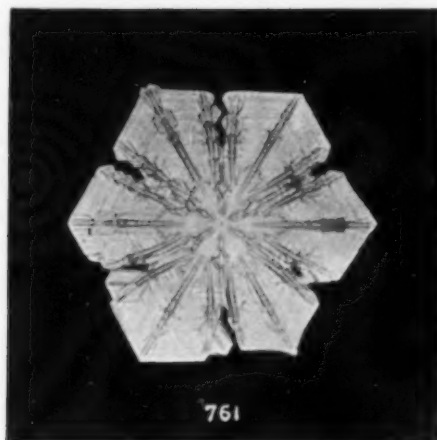
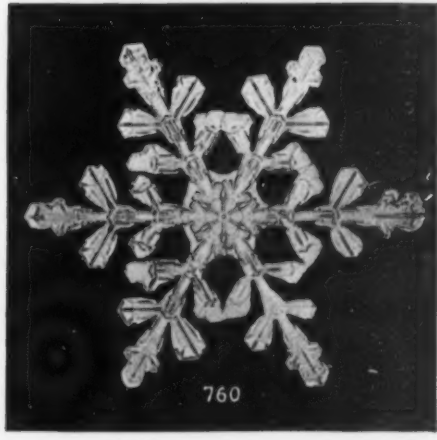
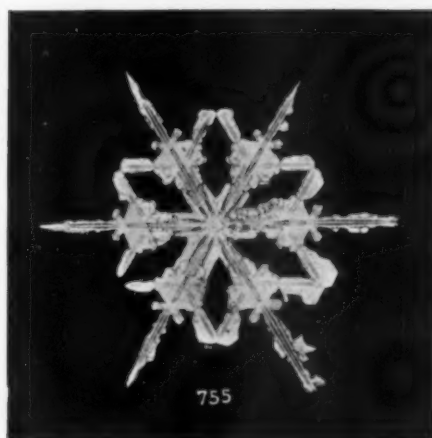
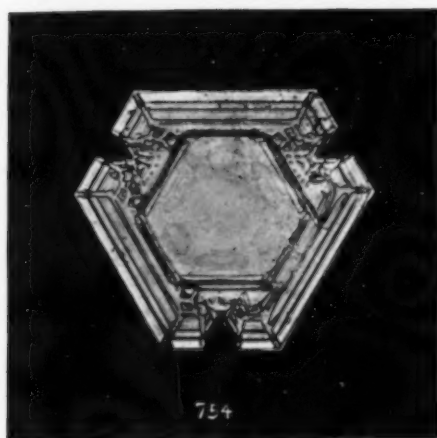
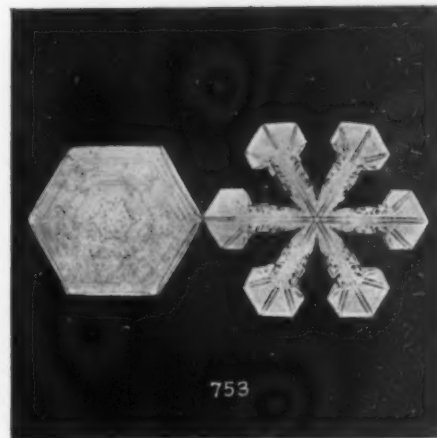
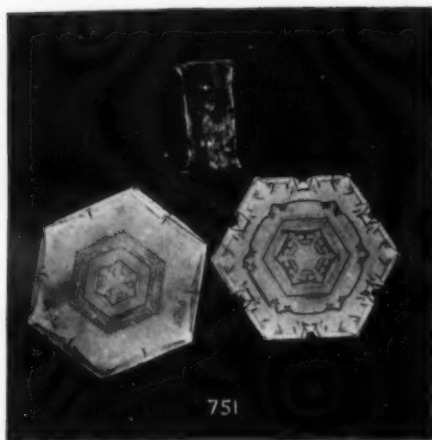




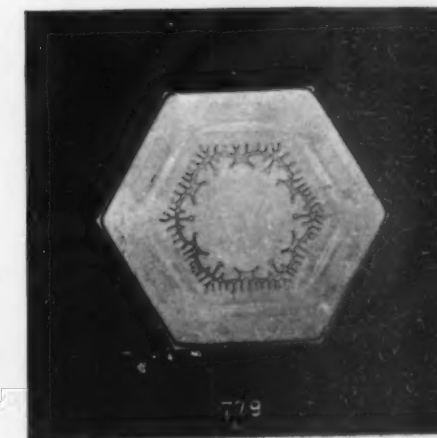
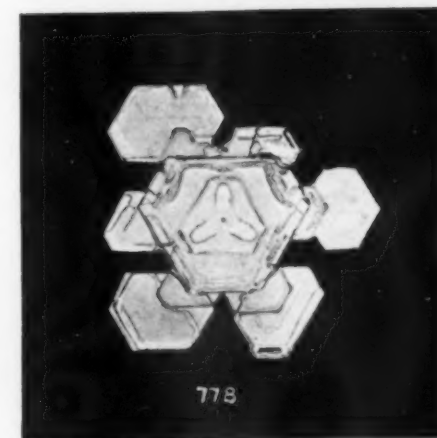
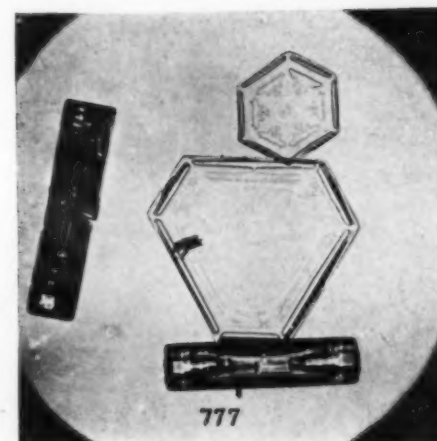
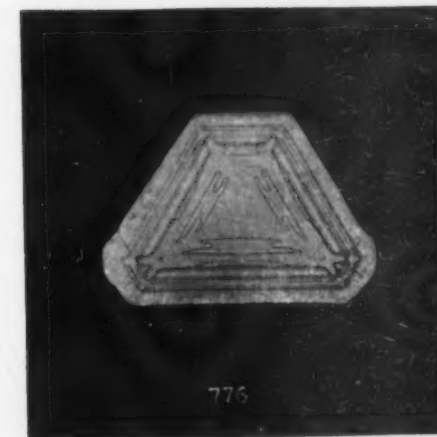
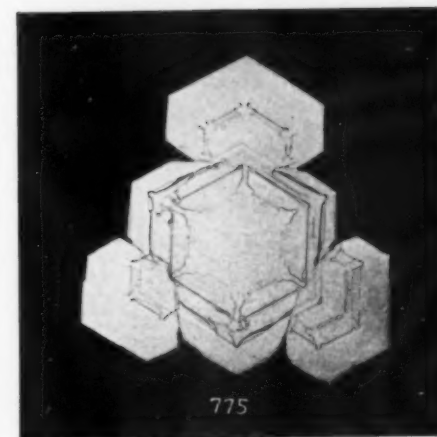
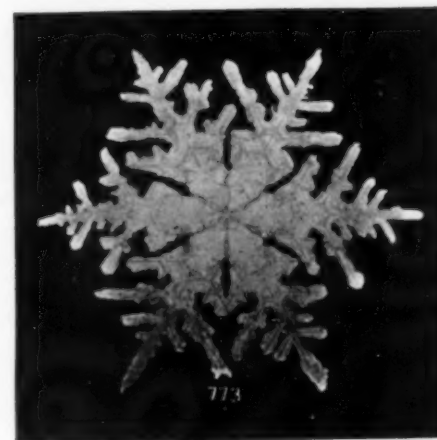
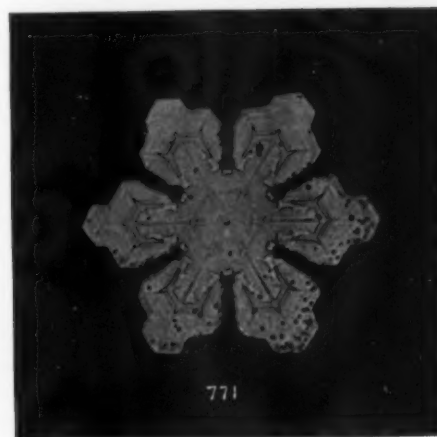
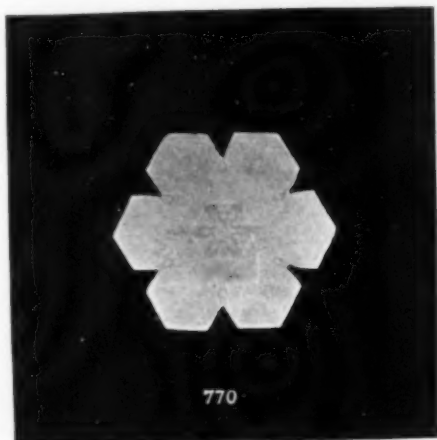
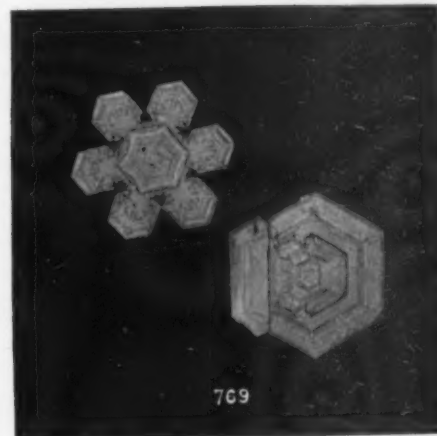
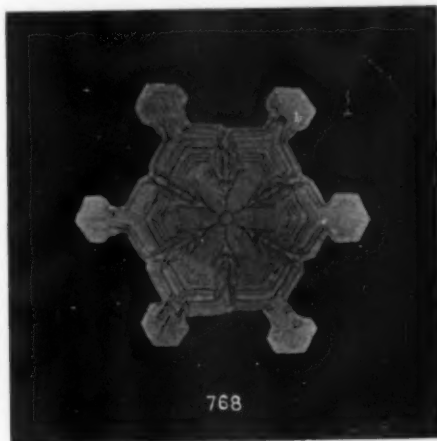




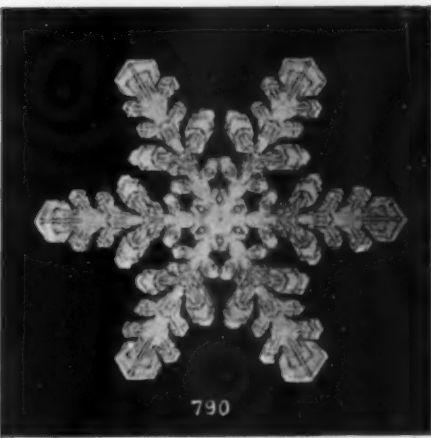
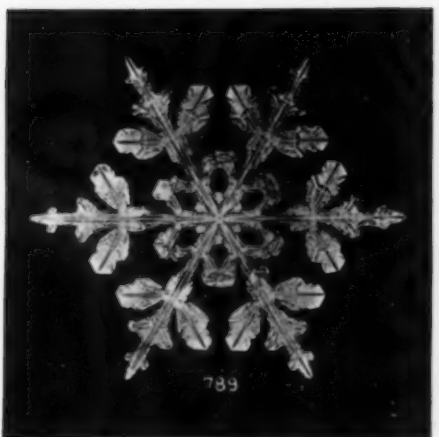
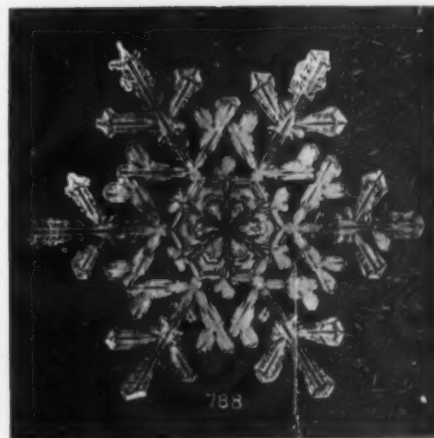
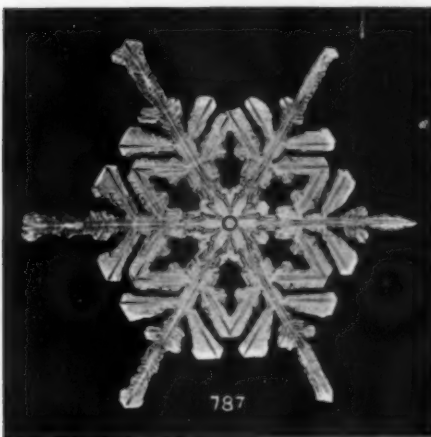
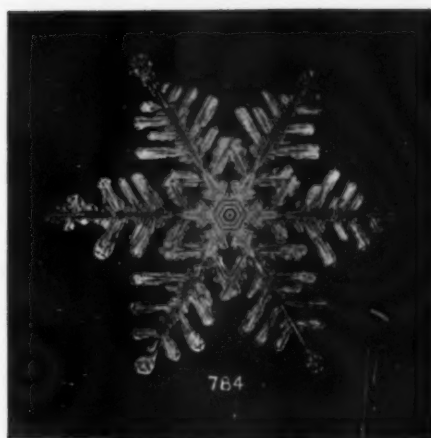
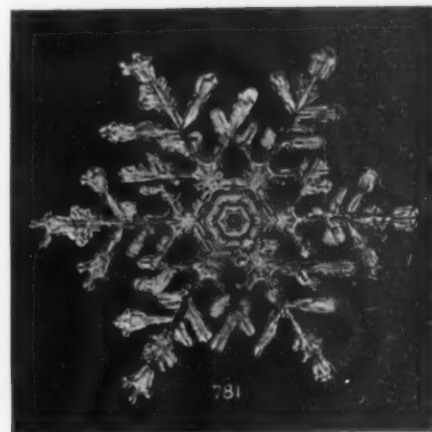




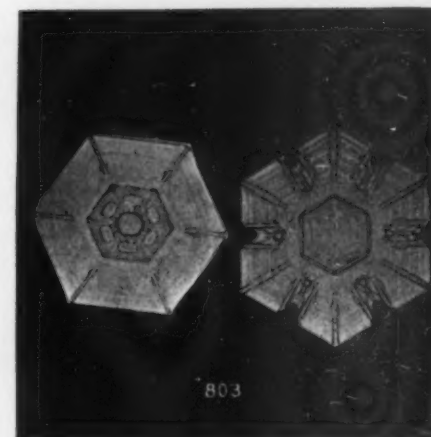
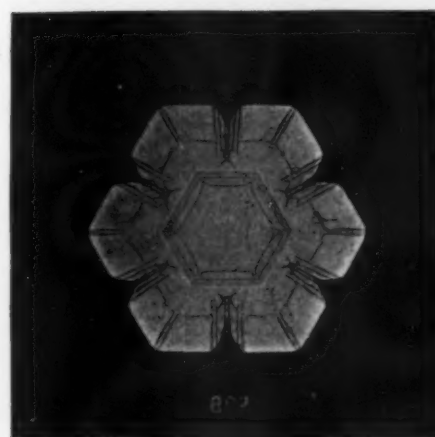
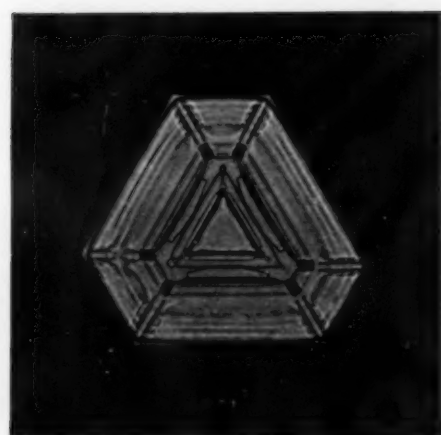
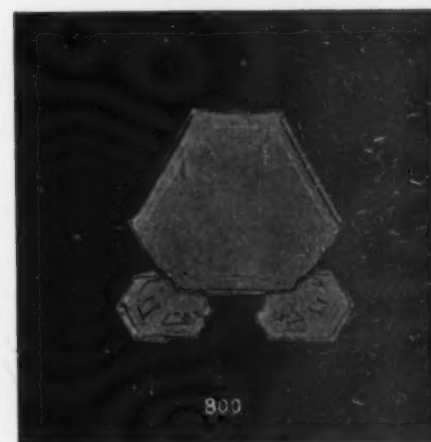
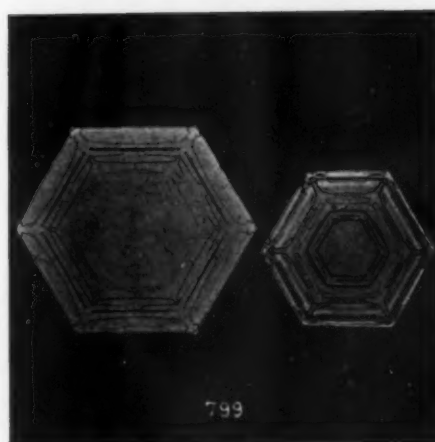
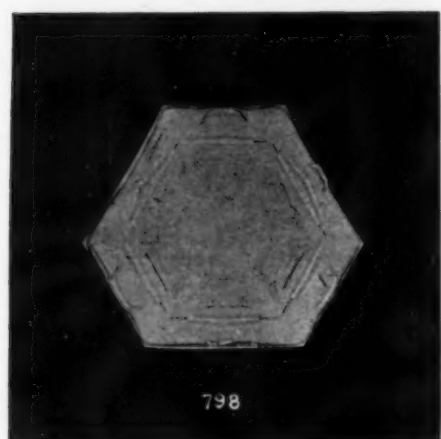
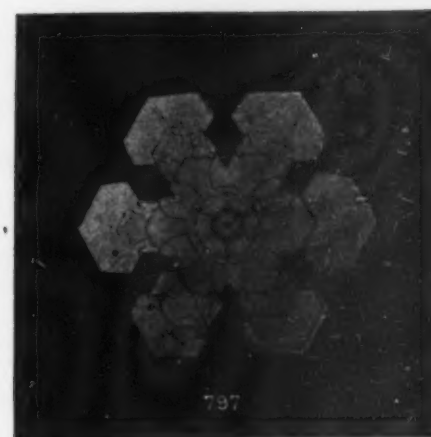
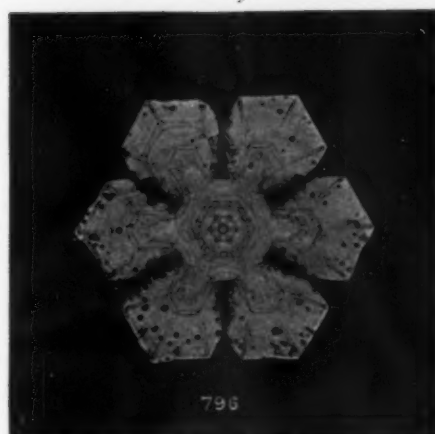
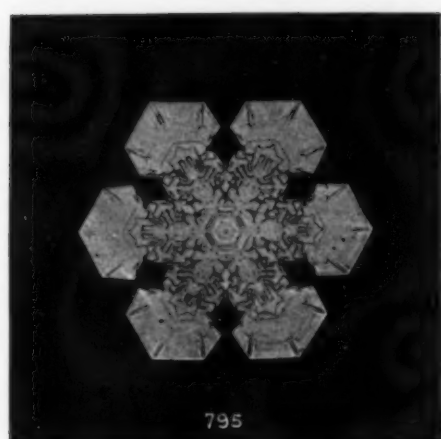




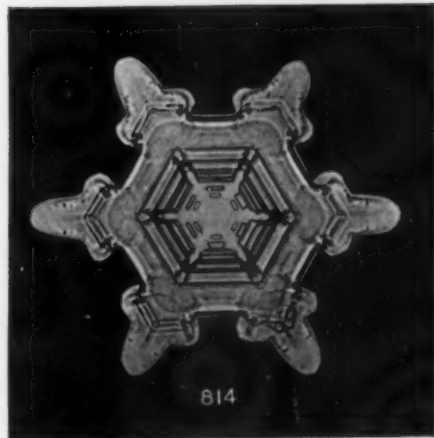
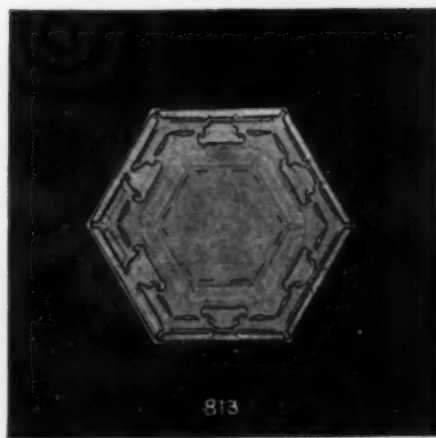
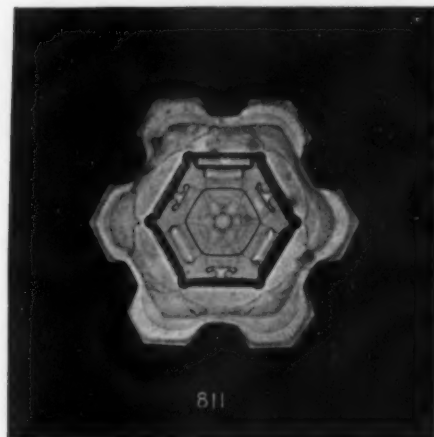
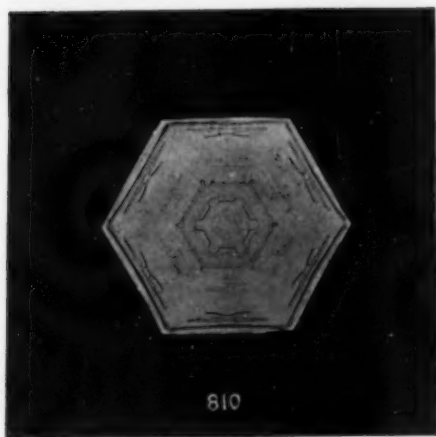
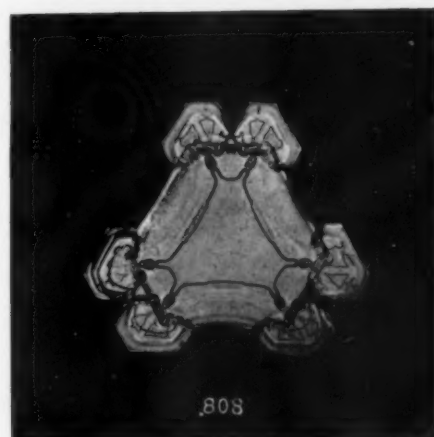
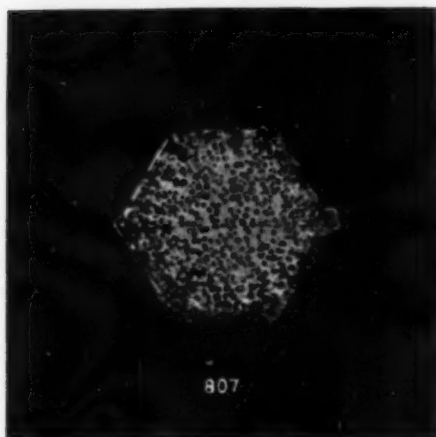
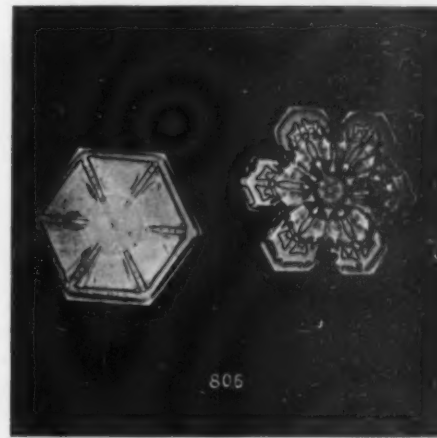
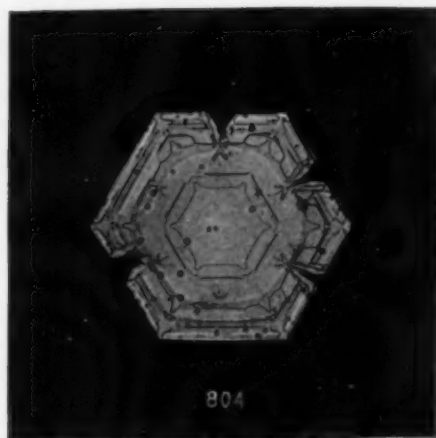




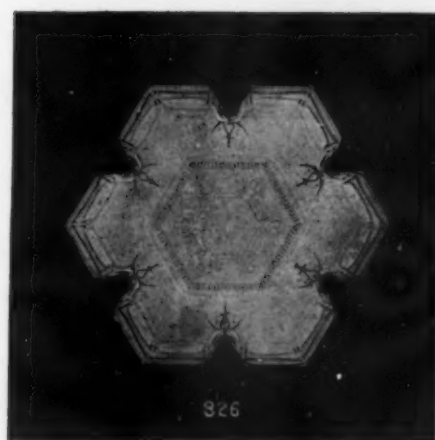
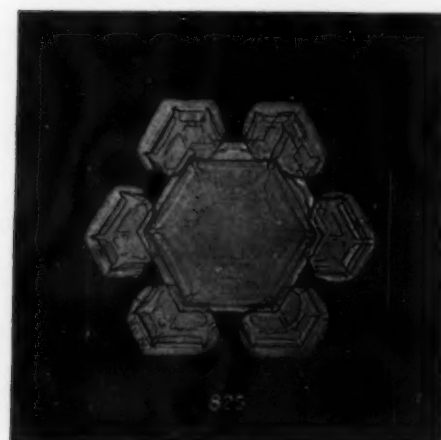
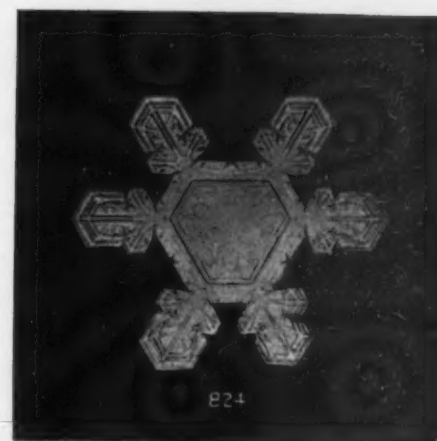
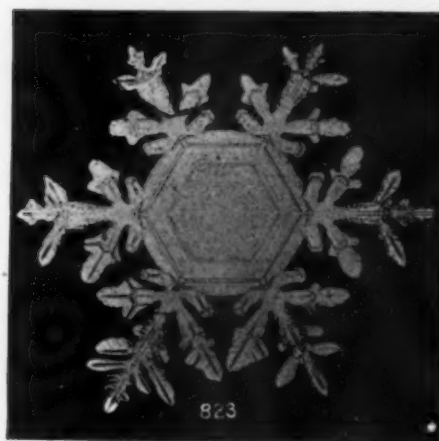
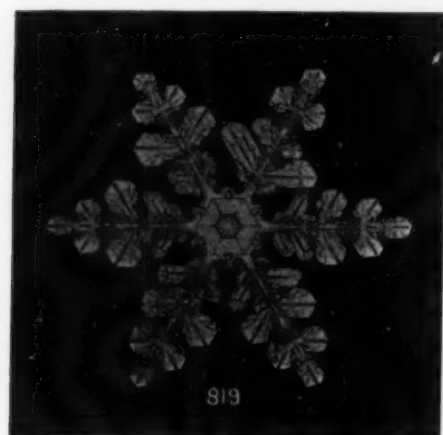
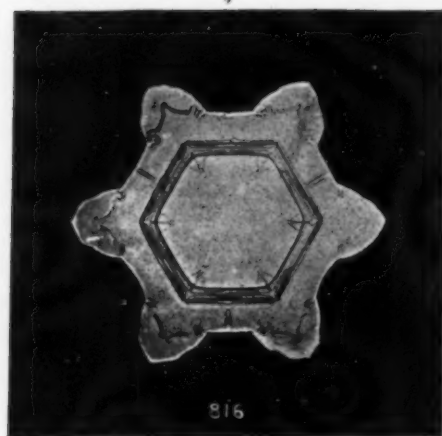




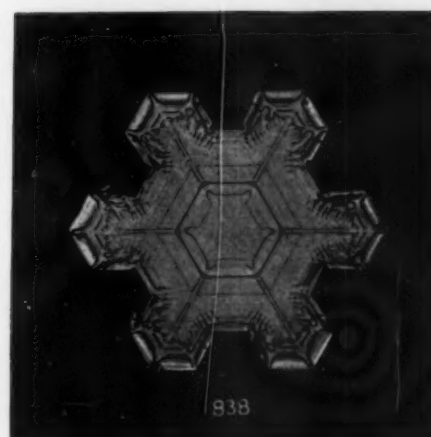
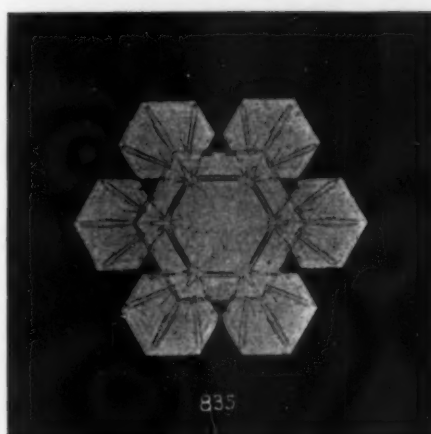
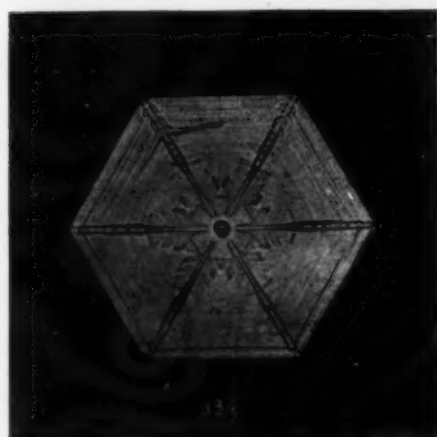
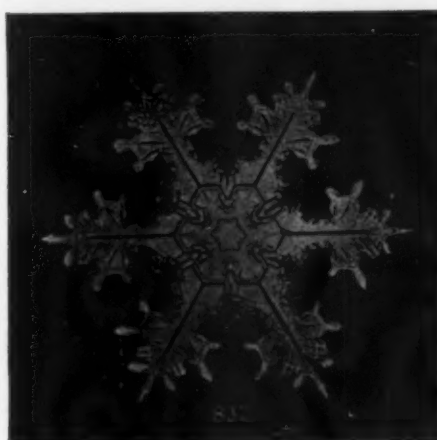
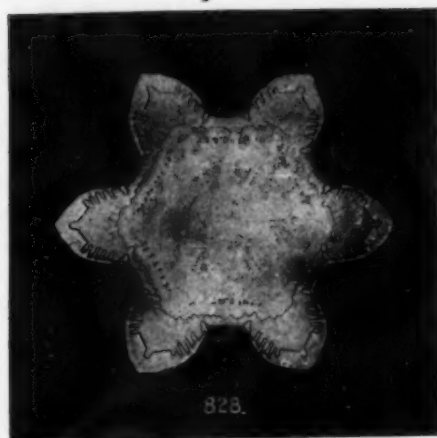




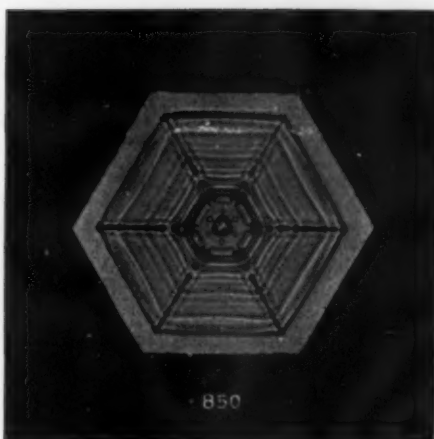
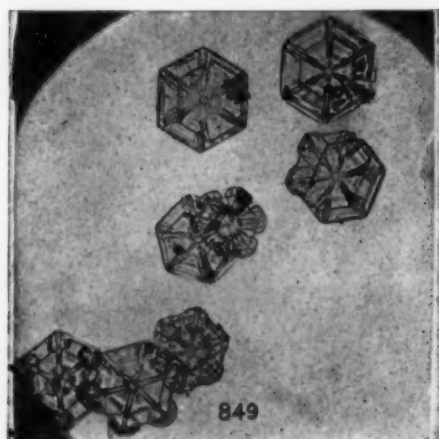
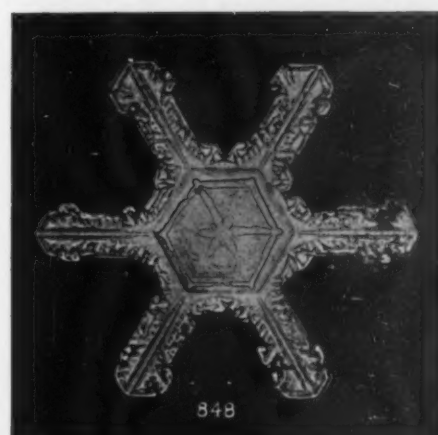
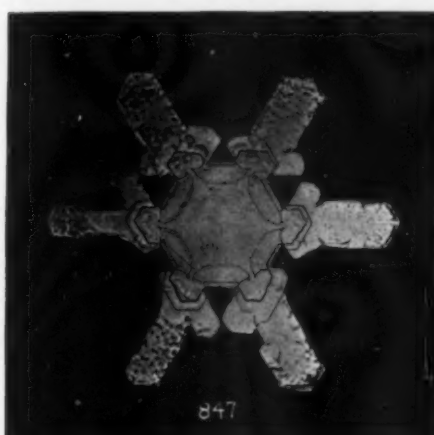
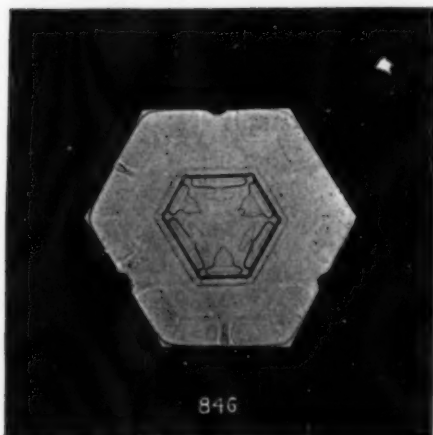
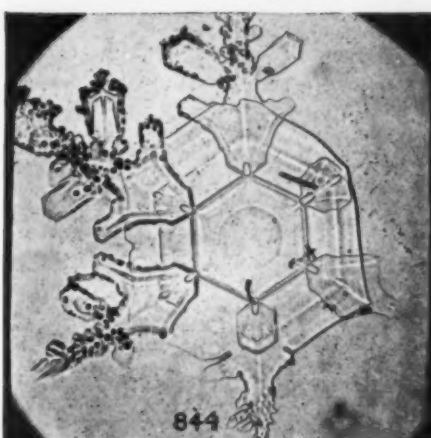
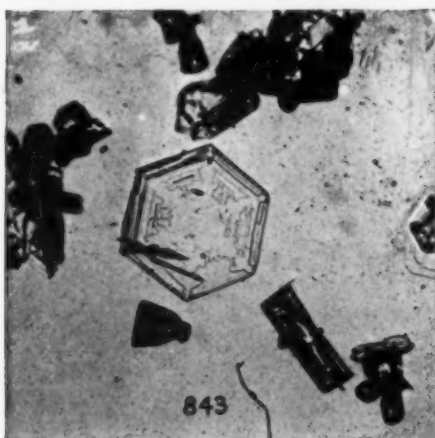


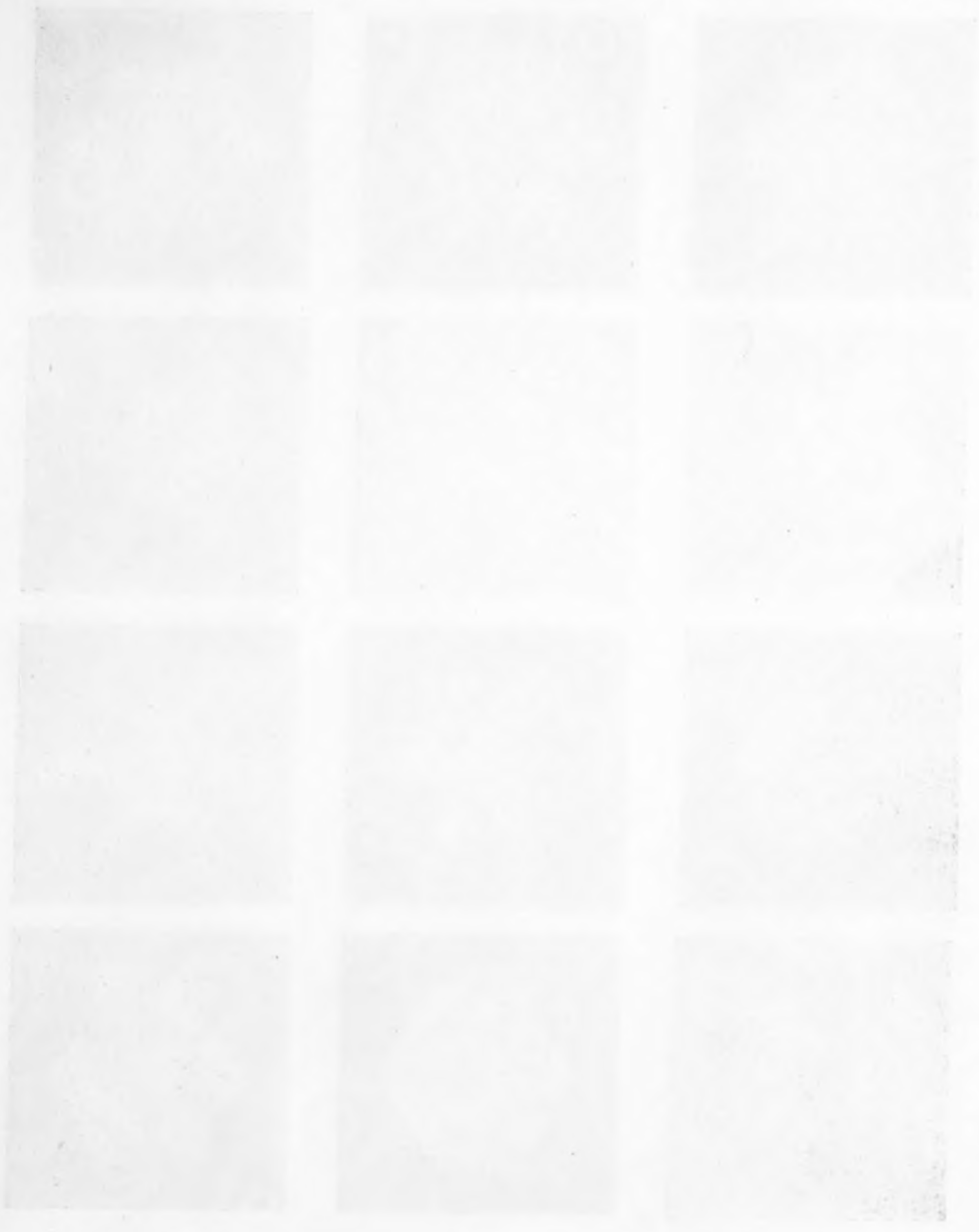


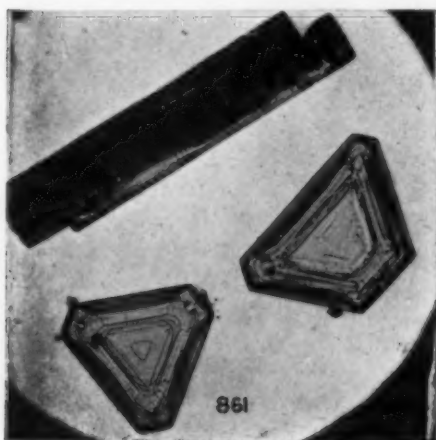
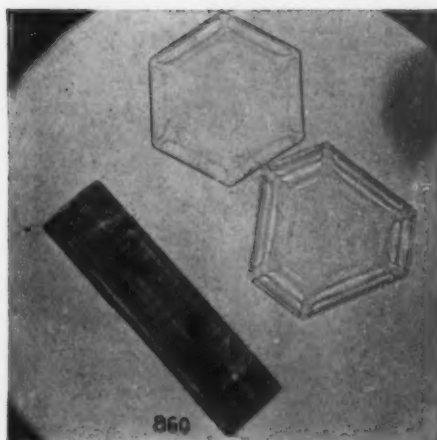
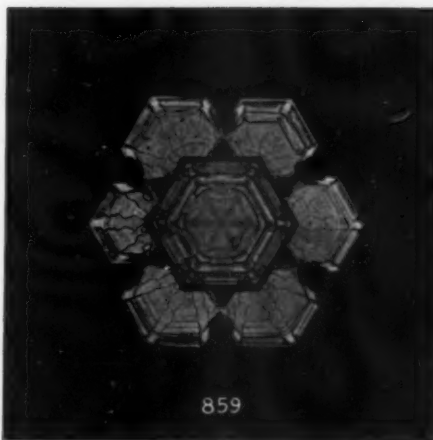
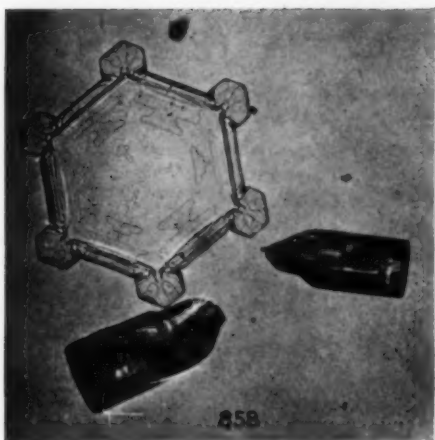
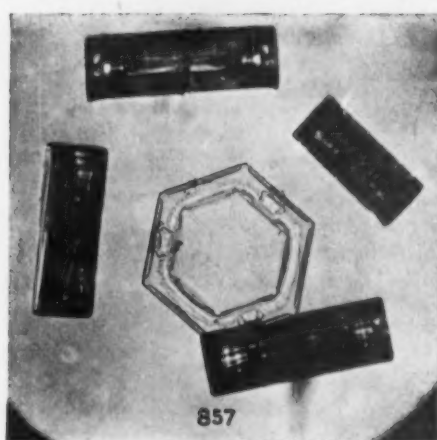
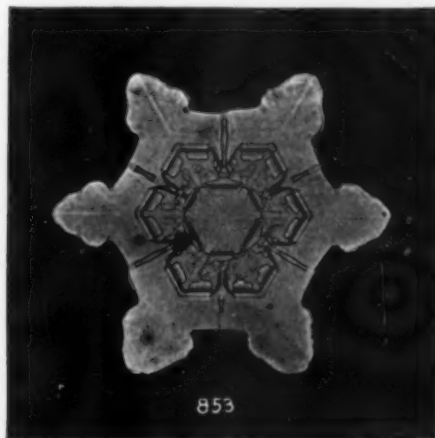




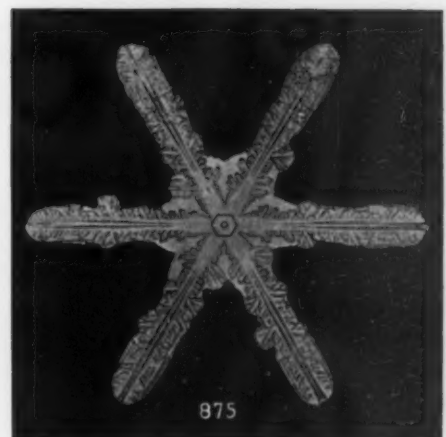
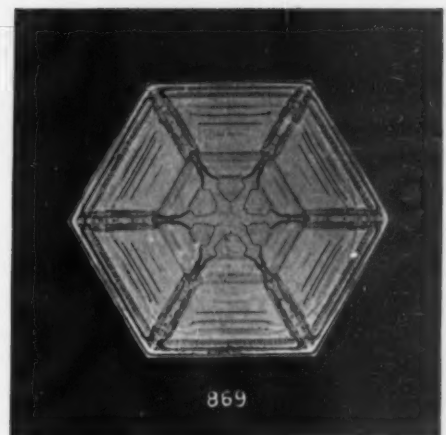
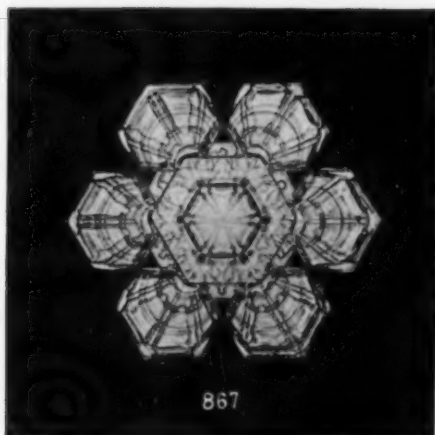
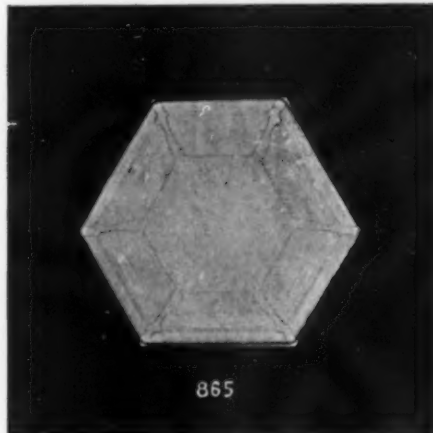
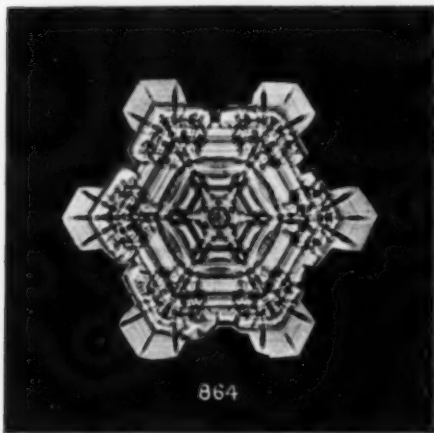




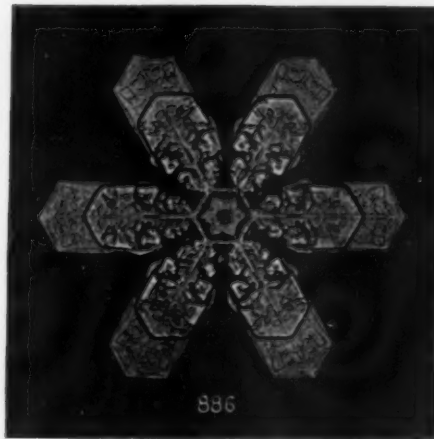
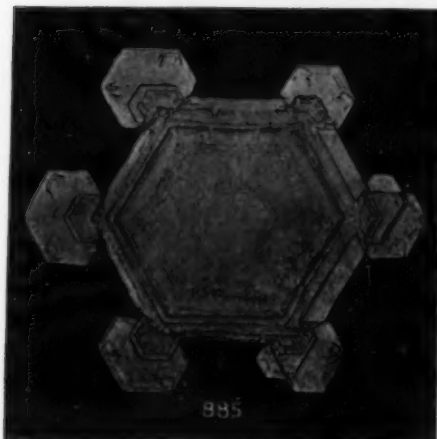
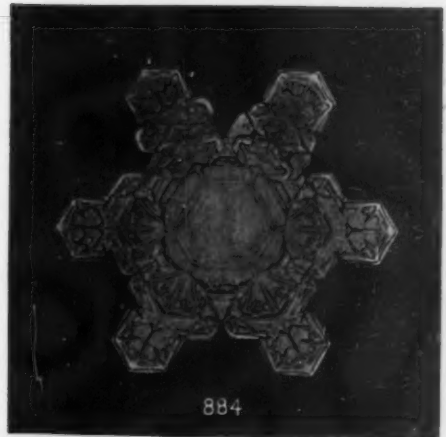
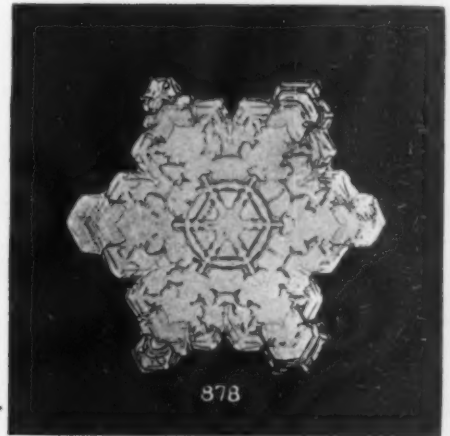
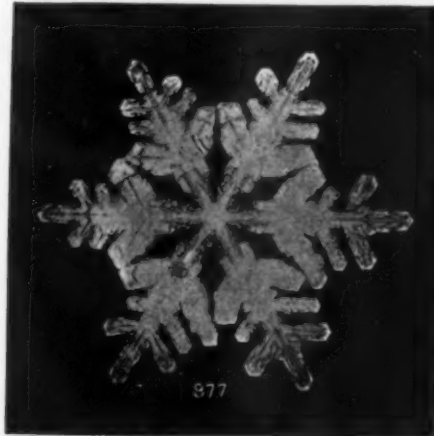






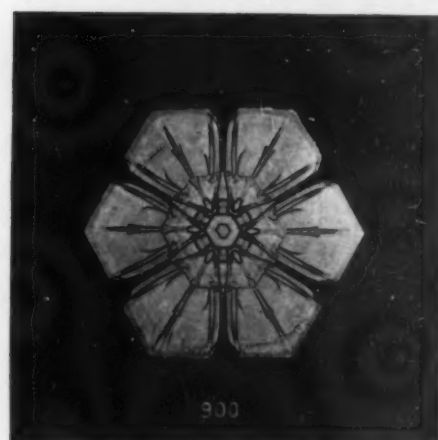
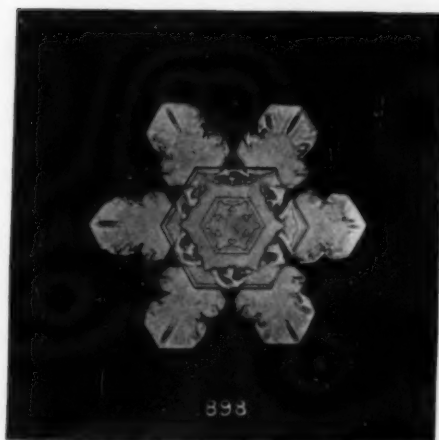
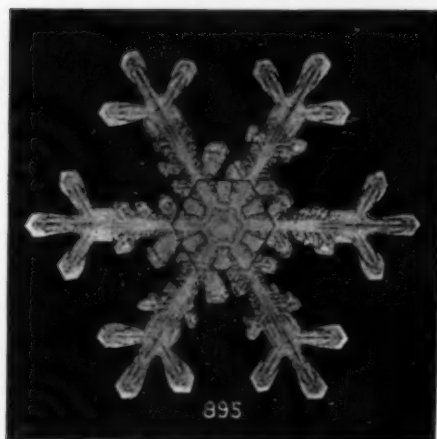
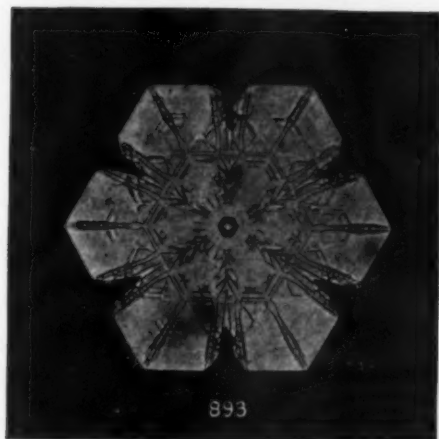
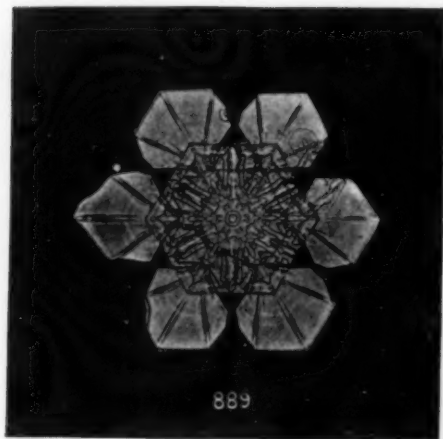




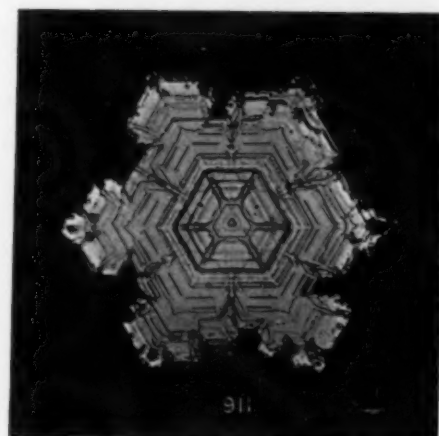
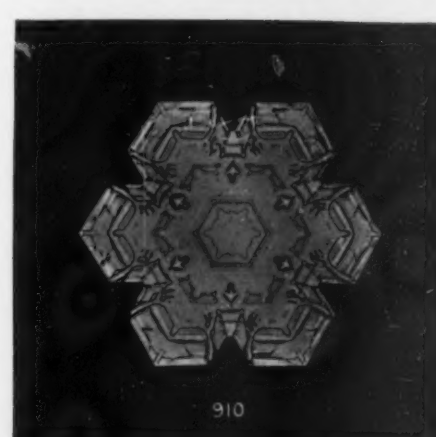
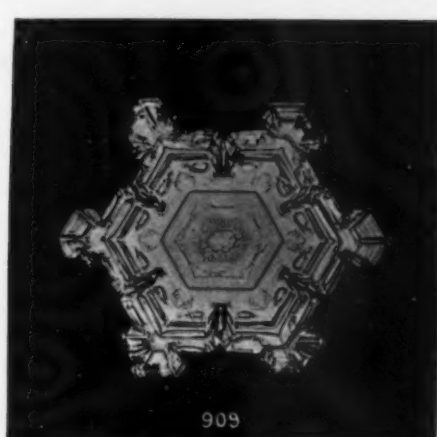
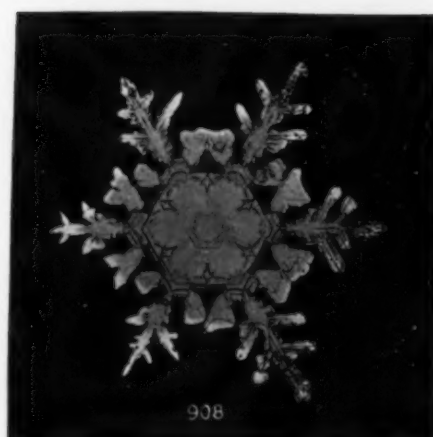
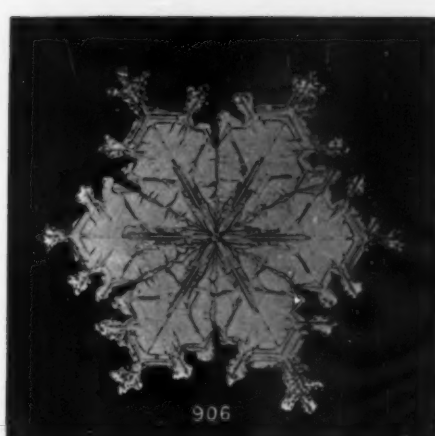
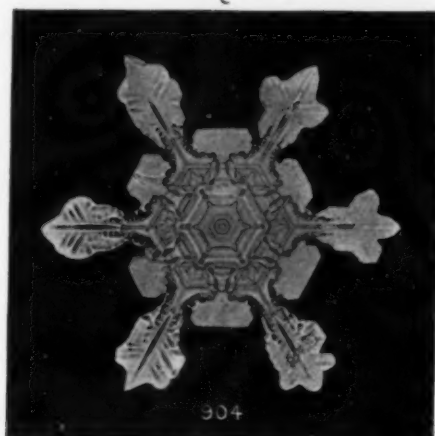
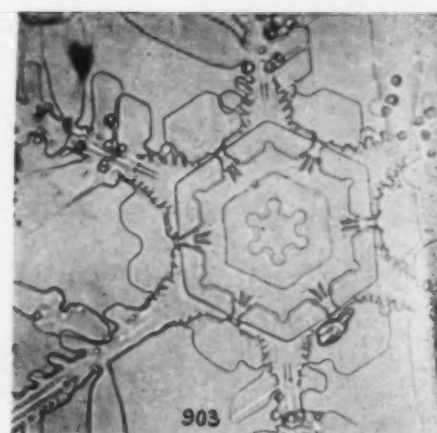


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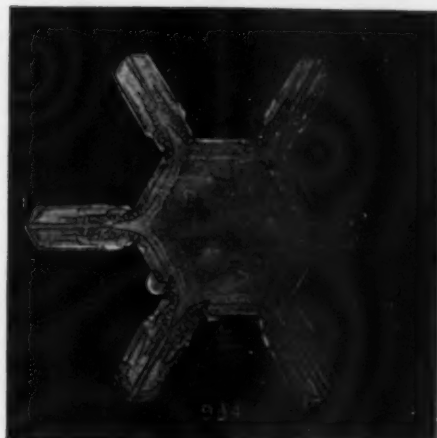
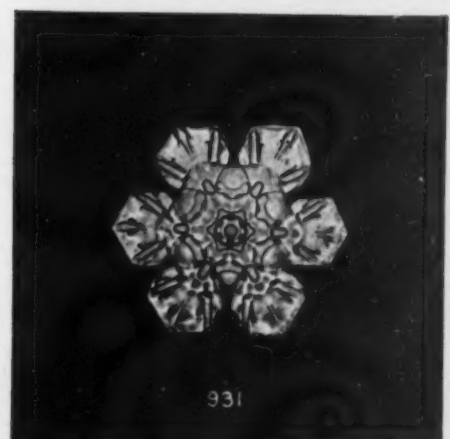
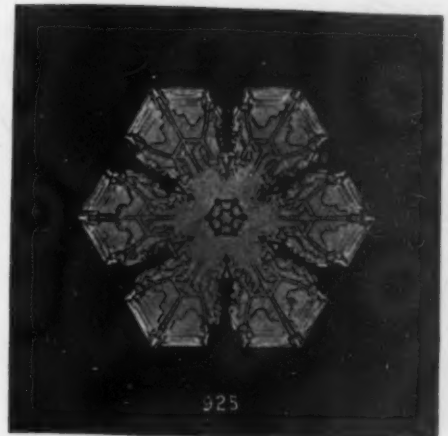
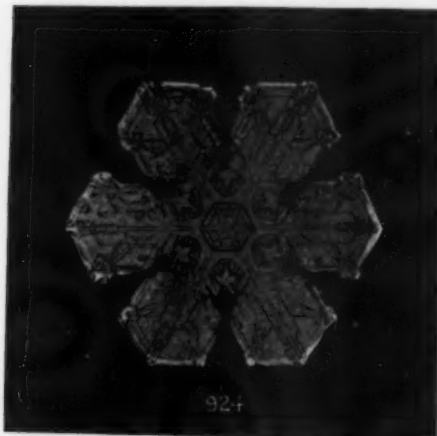
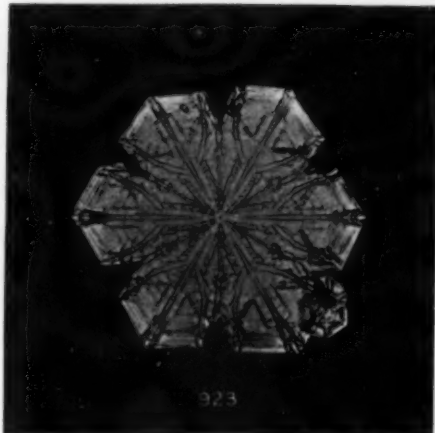












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XXX-139.

Photomicrographs of Snow Crystals.

Plate XXII.

